THE BULLETIN

OF THE

AMERICAN CERAMIC SOCIETY

Volume 20 DECEMBER, 1941 Number 12

ALEXANDER SILVERMAN

For story, see page 454

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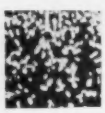

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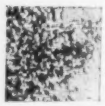

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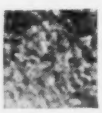

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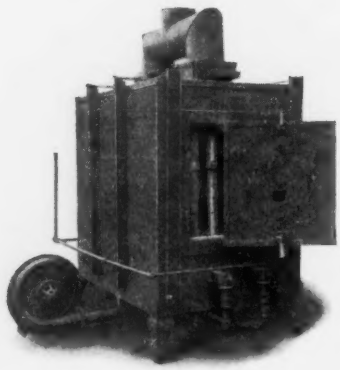

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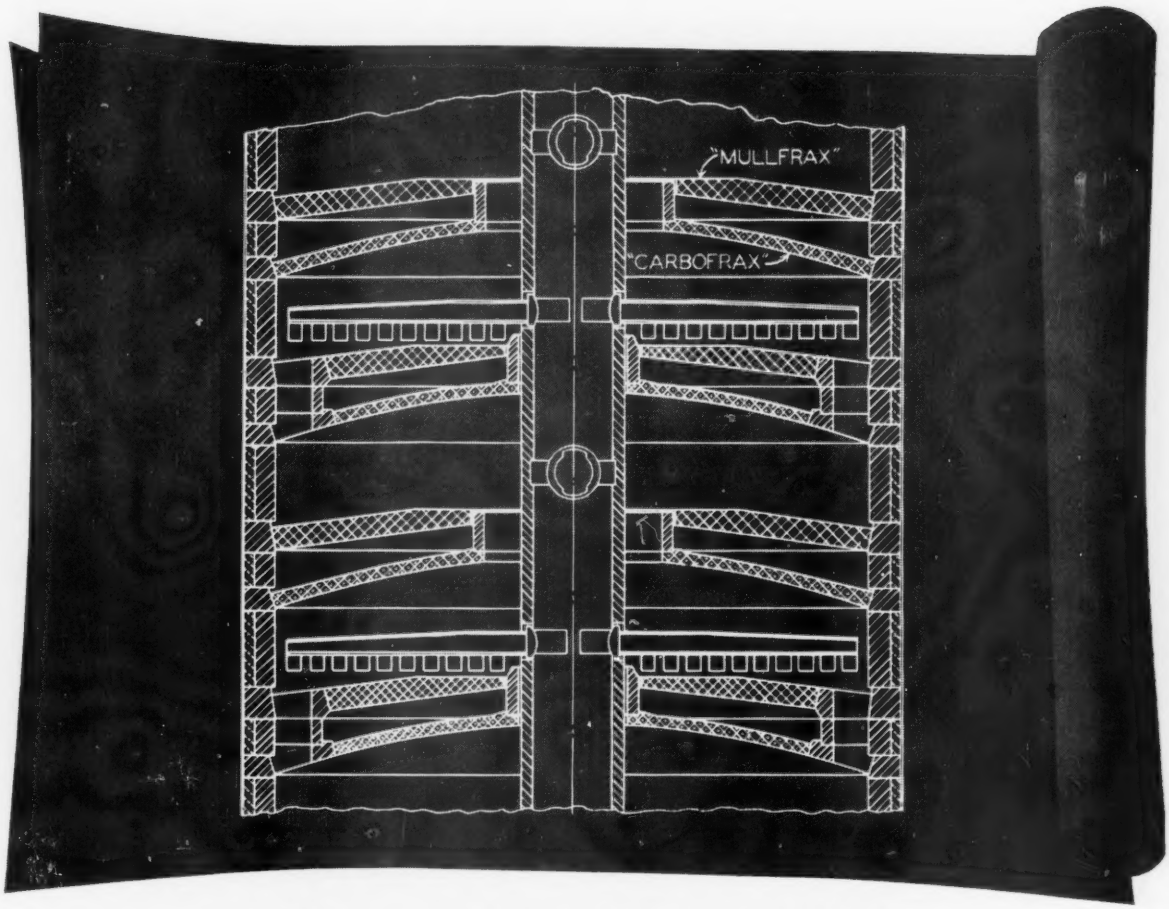

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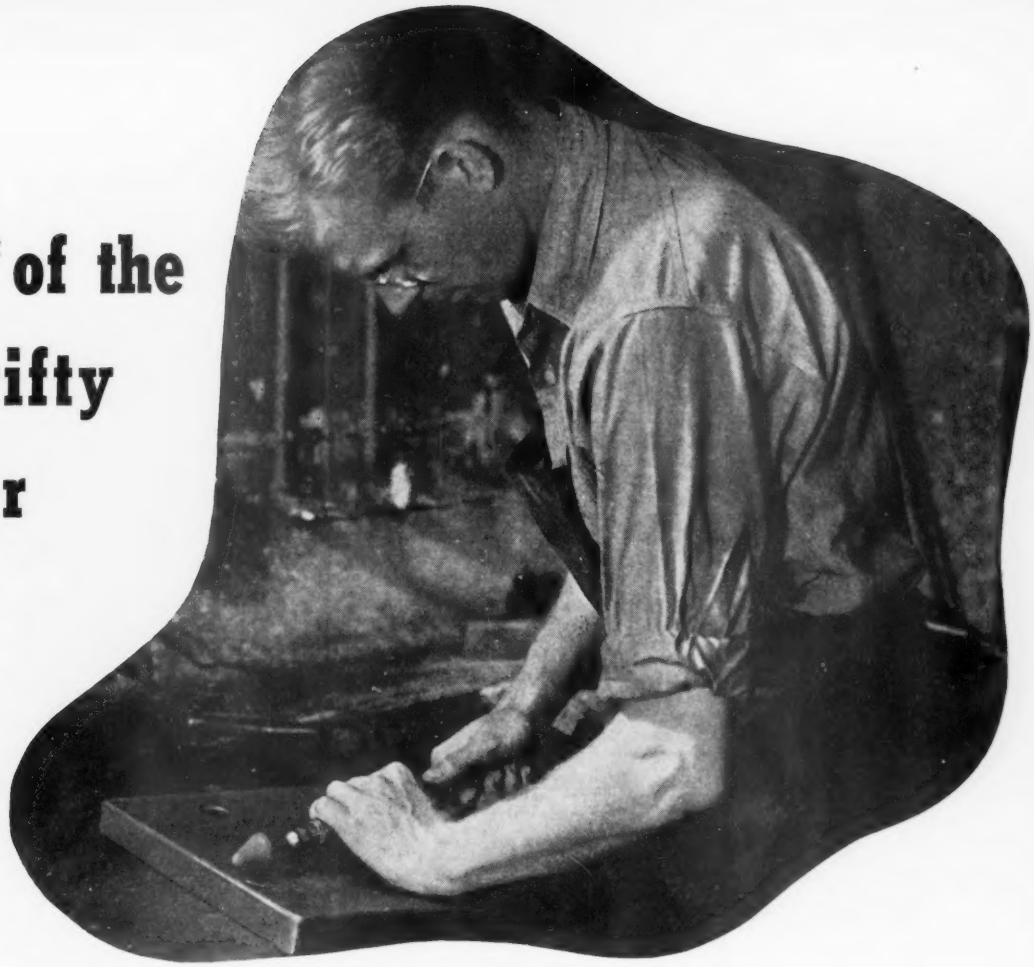

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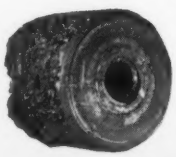
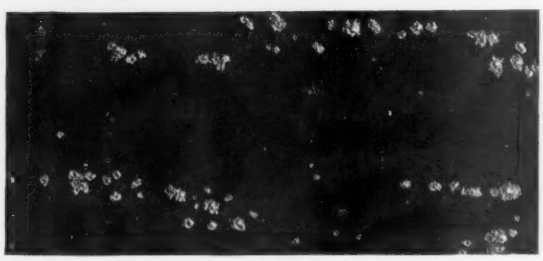


• The faulty grinding wheel. See how the silicon carbide on the sides has been worn down to the lead washer.



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(3) The new Corhart Electrocast paving is being laid on a bed of specially prepared Corhart Grain.

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Volume 20 DECEMBER, 1941 Number 12

PAPERS

MODULUS OF ELASTICITY OF DINNERWARE BODIES BY A SONIC-VIBRATION METHOD *

By S. V. Forgue and G. A. Loomis

Abstract

The elastic moduli of six commercial dinnerware bodies (three vitreous and three semi-vitreous) were determined by a sonic-vibration method and by a refinement of the stress-strain method. Three sizes of test bars were used to obtain some indication of the validity of the sonic formula with respect to the bar dimensions when the proper minimum ratio of length to thickness is maintained.

Comparative data are presented. The results indicate that the size of the test bar is immaterial if the proper minimum ratio of length to thickness is maintained; in the case of unlapped bars which are not of uniform thickness, this dimension should be greater than 1/4 inch. The values obtained by the stress-strain method compare favorably with those by the sonic method, especially for the vitreous bodies; the sonic method, however, gives more consistent results and requires less time than the stress-strain method.

I. Introduction

The modulus of elasticity is a factor that affects resistance to heat shock, but the stress-strain apparatus and the procedure which has been used to determine this property have not given sufficiently accurate values to correlate this property with other physical properties. The usual procedure, such as that suggested in The American Ceramic Society Standard Test Methods,[1] may cause an error of 20%, which is the permissible deviation from the average obtained by such procedure.

In the present investigation,† the elastic moduli of six commercial dinnerware bodies were determined by a sonic-vibration method and by a refinement of the stress-strain method, both of which will be described in detail and the results compared.

A general investigation of the sonic-vibration properties of dinnerware bodies was suggested by Koenig[2] in a qualitative study of the pitch and decay of tone of some sanitary porcelain bodies.

II. Review of Literature

When a bar that is thin with respect to its length is set into vibration at one of its natural frequencies, the magnitude of this frequency is determined only by the dimensions of the bar and by the density and elastic modulus of the material of which the test bar is composed. If, then, the frequency, density, and dimensions of the bar are measured, the modulus of elasticity may be computed. The relation between the elastic modulus and these other physical constants becomes relatively simple for a test bar of uniform cross section if the dimensions of the bar are chosen so that its length is great compared to its thickness in the plane of vibration. The derivation of this simplified equation is given in many textbooks on vibration and sound.[3] For a more general case, wherein the length of the specimen is not necessarily great compared to its thickness, a more complete theoretical solution for a bar vibrating in flexure has been worked out by Mason[4] and will be referred to later.

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 2, 1941 (White Wares Division). Received September 2, 1941.

[1] Standards Report, *Jour. Amer. Ceram. Soc.*, **11** [6] 517–19 (1928).

† Valuable suggestions have been given by L. H. Milligan of the Norton Company, and his assistance is gratefully acknowledged.

[2] C. J. Koenig, "Use of Nepheline Syenite in Sanitary Porcelain," *Jour. Amer. Ceram. Soc.*, **22** [2] 35–38 (1939); p. 38.

[3] (*a*) Lord Raleigh, Theory of Sound, Vol. 1, Chapt. VIII. Macmillan Co., London, 1937.

(*b*) H. B. Wood, Textbook of Sound, pp. 107–12. Macmillan Co., New York, 1930.

(*c*) E. H. Barton, Textbook on Sound, pp. 287–90. Macmillan Co., New York, 1914.

(*d*) P. M. Morse, Vibration and Sound, p. 123. McGraw-Hill Book Co., New York, 1936.

[4] W. P. Mason, "Motion of Bar Vibrating in Flexure, Including Effects of Rotary and Lateral Inertia," *Jour Acoustical Soc. Amer.*, **6**, 246–49 (April, 1935).

Many investigators have employed the sonic-vibration method of determining the elastic modulus and have compared the results obtained with those found from static stress-strain methods. Powers[5] thus found good agreement between the two methods in the case of concrete. Grime[6] had good results with circular steel bars, using a longitudinal vibration method which he also applied to tests on roofing tile, asbestos-cement sheeting, brick, and mortar. Grime and Eaton,[7] who employed a lateral vibration with such materials as lead, ebonite, wallboard, paraffin wax, rock asphalt, and asphalt mastic, reported satisfactory results. They found that the change in vibration in such materials of high internal friction due to the damping was practically negligible. Obert[8] found good agreement between the two methods for such building materials as stone and concrete wherein the specimens were under zero stress or applied stress up to failure. Hornibrook[9] has set up a sonic testing apparatus at the National Bureau of Standards, and a variation of this method has been the determination of Young's modulus by using circular loops of wire as described by King.[10]

III. Procedure

(1) Forming and Firing Test Bars

Six commercial dinnerware bodies were supplied by the producer for use in this study; three were semi-vitreous bodies and three were vitreous. The test bars were slip-cast using a sufficient number of molds so that all of the specimens of a body could be cast at one time and left in the molds until they were leather-hard. The bars thus were uniform in cross section and free from warpage in drying.

To determine the effect of size of the specimen on the modulus of elasticity determinations, three sizes of bars were made from each body with the respective dimensions (mold sizes) of $^1/_4$ by 1 by 7 in., $^3/_8$ by 1 by 7 in., and $^1/_2$ by 2 by 14 in. Twelve bars of each size were cast from each body.

Except in the case of body S4, the three sets of bars of each body were fired at the pottery that supplied the respective samples. Care was exercised in placing the bars so that they would fire straight and in such kiln positions that each bar of a single body would receive the same heat treatment. Body S4 was fired in a laboratory kiln on a schedule approximating the plant firing of this body. Although there was only $^1/_2$ cone difference between the saggers, this firing was not so uniform as those for the other sets of bars.

(2) Sonic-Vibration Method

Because the test bars were long in comparison with their thickness, the simplified formula previously mentioned was used in this investigation. This formula, which relates to the natural frequencies of a slender bar of uniform cross section and homogeneous material, is as follows:

$$f = \frac{m^2 k}{2\pi l^2}\sqrt{E/D}. \qquad (1)$$

f = natural frequency of vibration.
m = factor depending on mode of vibration (which is 4.73 for fundamental mode of free-free bar).
k = radius of gyration of cross section about axis in section perpendicular to plane of vibration.
($k = d/4$ for circular bar of diameter, d, or $t/\sqrt{12}$ for rectangular bar of thickness, t, in plane of vibration.)
l = length of bar.
E = Young's modulus of elasticity.
D = density of material composing bar.

Solving equation (1) for E gives

$$E = \frac{48\pi^2 l^4 f^2 D}{m^4 t^2}. \qquad (2)$$

A convenient form of equation (2) for rectangular bars was found to be

$$E = \frac{1.372 \times 10^{-5} l^4 D f^2}{t^2} \text{ lb./sq. in.} \qquad (3)$$

l and t = length and thickness (cm.), respectively.
D = density (gm./cc.).
f = frequency (cycles/sec.) for fundamental mode of vibration of free-free bar.

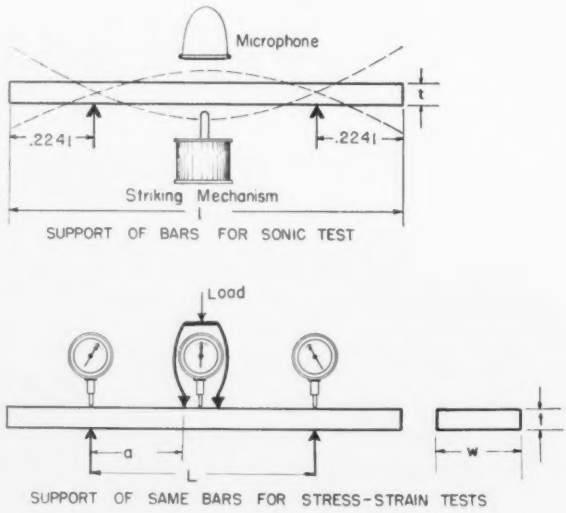

FIG. 1.

In the case of the fundamental mode of a free-free bar, the bar is supported without restraint at its two nodes of vibration, which can be shown to be located at 0.224 l from either end of the bar (Fig. 1). When it is

[5] T. C. Powers, "Measuring Young's Modulus of Elasticity by Means of Sonic Vibrations," *Proc. Amer. Soc. Testing Materials*, **38** [Part II] 460–69 (1938).
[6] G. Grime, "Determination of Young's Modulus for Building Materials by a Vibration Method," *Phil. Mag.*, **20**, 304–10 (August, 1935); *Ceram. Abs.*, **15** [5] 150 (1936).
[7] G. Grime and J. E. Eaton, "Determination of Young's Modulus by Flexural Vibration," *Phil. Mag.*, **23** [152] 96–98 (1937); *Ceram. Abs.*, **16** [7] 223 (1937).
[8] Leonard Obert, "Sonic Method of Determining Modulus of Elasticity of Building Materials Under Pressure," *Proc. Amer. Soc. Testing Materials*, **39**, 987–95, December, (1939).
[9] F. B. Hornibrook, "Discussion on Application of Sonic Method to Freezing and Thawing Studies of Concrete," *ibid.*, pp. 996–97.
[10] Allen King, "New Method of Measuring Young's Modulus," *Rev. Sci. Instruments*, **11** [7] 114–16 (1940).

supported at these nodes, the bar is free to vibrate at its natural frequency.

For bars which are not long compared to their thickness, Mason[4] has shown that the effects of rotary inertia and lateral expansion and contraction of the bar must be considered. He also showed that the rotary inertia may be allowed for by a suitable choice of the factor, m, in equation (2). He gives a graph relating m to R, in which R is the ratio of thickness to length; to allow for both effects, it is necessary only to replace R by $R(1+\theta)^{1/2}$, wherein θ is Poisson's ratio, and to find the m, which corresponds to a ratio of thickness to length of $R(1+\theta)^{1/2}$.

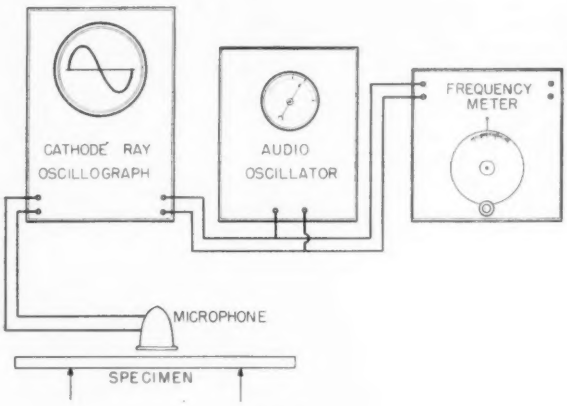

FIG. 2.

As the bars used in this investigation were reasonably long compared to their thickness the simplified equation (3) was found to be adequate.

The bars were supported on two taut strings at the nodes, each string being attached to its own small metal frame on the supporting device. The distance between the two strings could be adjusted on this device for different lengths of specimens by a screw arrangement which moves the metal frames. The bars were set into vibration by an electrical solenoid striking mechanism (such as is used in doorbell chimes), which was located below the midpoint of the test bar. The location of the bar on the supports was not critical inasmuch as a small movement of the supports away from the nodal points had a negligible effect on the frequency at which the bar vibrated, nor did the location of the striking mechanism affect the vibration frequency. For other sonic tests, however, such as decay of tone measurements, the effect of shifting the supports would introduce serious errors.

The audible tone given off by the vibrating specimens was picked up by a crystal microphone which was connected directly to the vertical deflection circuit of a cathode-ray oscillograph. When the oscillograph sweep frequency was applied to the horizontal deflection circuit and suitably adjusted, it was possible to see the wave form of the bar vibrations. This vibration was always found to be nearly a pure sine wave on the oscillograph screen as far as the eye could judge.

To determine the frequency of the vibration picked up by the microphone, the output of a variable frequency audio-frequency oscillator (instead of the oscillograph sweep frequency) is applied to the horizontal deflection circuit of the oscillograph.

It can be shown[11] that when the oscillator frequency is adjusted so that the pattern on the screen of the oscillograph takes the form of an ellipse, the frequency impressed on the vertical deflection plates of the oscillograph must be equal to that on the horizontal deflection plates. This means, in the present case, that the audio oscillator frequency has been adjusted so that it is equal to that of the test bar. If, then, the oscillator were calibrated, the frequency could be read directly from the oscillator calibration.

A more accurate method of determining the frequency, however, is to measure the frequency of the oscillator signal by the General Radio type 434B audio-frequency meter which has a guaranteed accuracy of

[11] J. F. Rider, The Cathode Ray Tube at Work, pp. 77–92. John F. Rider, publisher, New York, 1935.

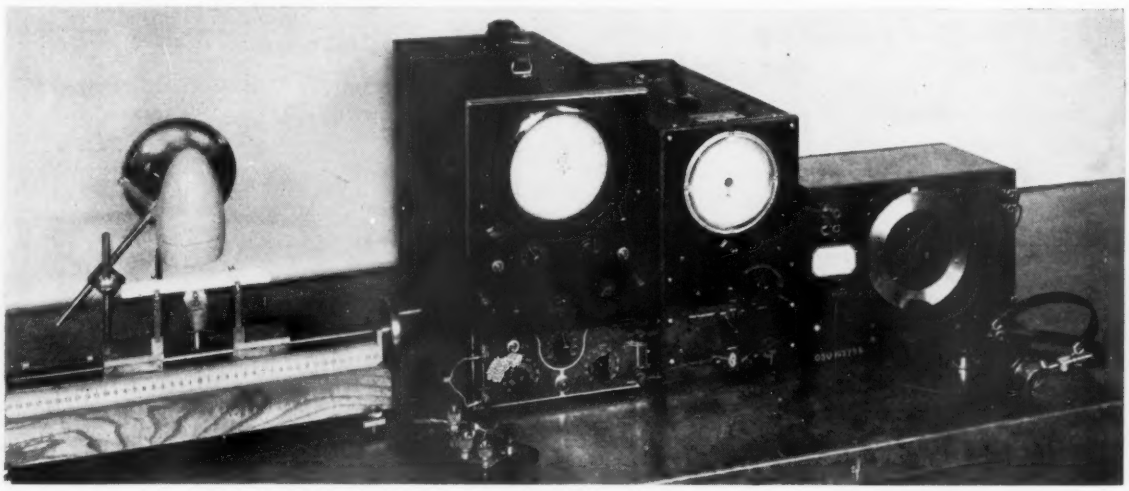

FIG. 3.

0.5% over its entire range, and frequency measurements may be repeated to an accuracy of about 0.2%. This method was finally employed after the calibration of the wave meter was checked for safety by standard sources over the entire range which was of interest in the present study.

Figure 2 shows a diagram of the apparatus used for the frequency determinations, and Fig. 3 shows a photograph of this apparatus, including the striking mechanism.

The density determinations were made on the whole bar, and the individual value (bulk density) obtained for each bar was used to calculate the elastic modulus for each particular bar. The volume was obtained by the suspended-weight method after the bars were boiled for 5 hours and cooled to room temperature in the water.

A discrepancy was found between the volume of the bars as determined by suspended weight and that obtained by calculation from the dimensions determined with a micrometer caliper even when the average of a large number of readings for each dimension was taken. The calculated volume was always the larger. By lapping some of the bars, this increase was found to be caused by slight irregularities in the surfaces of the bars so that the jaws of the micrometer always rested on high spots. Equation (4) was therefore derived and used to determine the error in the dimensions obtained with the micrometer calipers.

$$e = \frac{V' - V}{w'l' + l't' + w't'}. \qquad (4)$$

e = error in dimensions (assumed to be same for each).
V' = $t'w'l'$ (average thickness, width, and length measurements by micrometer calipers).
V = true volume by water suspension.

The true dimensions that were obtained by subtracting the values for e from the indicated dimensions were used to calculate the modulus of elasticity by the sonic formula (equation (3)) and also by the stress-strain method.

By using the corrected dimensions for unlapped bars, it was found that the moduli checked closely with values that were obtained on the same bars after lapping to obtain plane smooth surfaces and with no correction on their indicated dimensions.

(3) Stress-Strain Method

The stress-strain apparatus was designed and built to permit greater accuracy than is possible with the usual apparatus employed for the determination of modulus of elasticity of ceramic materials. Figure 4 is a photograph of the apparatus, and Fig. 1 shows how the specimens were supported and loaded. Its unique feature is the double knife-edge used to apply the load at the center of the specimen through an inverted U block, thus permitting the shanks of the three Ames dials to rest directly on the specimen. All of the "knife-edges" are removable, 1/4-inch round steel rods. The two at the center, about 1 inch apart, are set in rocking mechanisms which are provided with springs so that both will bear equally on the specimen over its entire width. One of the end rods is also set in a rocking support. The three 1/10,000-inch Ames dials are rigidly supported, but their position may readily be adjusted.

The loading of the specimens was obtained by the use of a series of dead weights applied directly; a lever arrangement was unnecessary with the maximum loading that is possible for these relatively thin bars.

In determining the modulus of elasticity by this method, an equation was used for a simple beam with two symmetrical loads and supported at both ends[12]; for a rectangular bar, this equation may be expressed as follows:

$$E = \frac{Ma(3L^2 - 4a^2)}{4wt^3y}. \qquad (5)$$

E = Young's modulus of elasticity (lb. per sq. in.).
M = load (lb.) applied to test bar (i.e., total load on two knife-edges after initial reading of dials).
a = distance (in.) from end knife-edge to nearer of two center knife-edges.
L = distance (in.) between end knife-edges.
w = width (in.) of test bar.
t = thickness or depth (in.) of test bar.
y = deflection (in.) of test bar.

[12] Cambria Steel Hand Book, p. 163. Cambria Steel Co., Philadelphia, Pa., 1919. For a rectangular bar, I, the moment of inertia in the equation is $wt^3/12$.

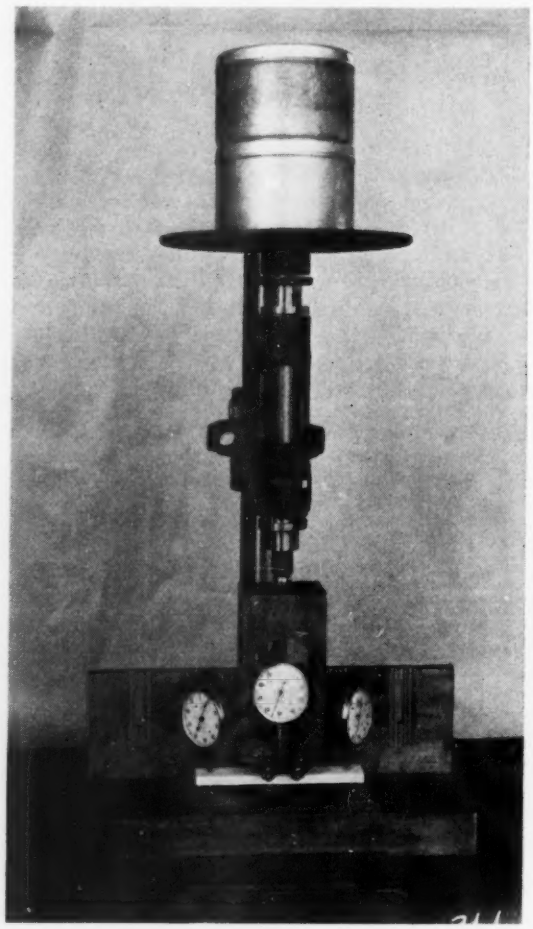

FIG. 4.

Equation (5) does not take into account the effect of shear, but it was found by calculation that when $a = 2$ in. and $L = 5$ in. or $a = 4^1/_2$ in. and $L = 10$ in., the conditions under which the short and long bars, respectively, were tested, the effect of shear was negligible (about 0.5% for $L = 5$ in.), and it was therefore not taken into account.

In using equation (5), the ratio of M/y was obtained by measuring the slope of the load-deflection curves. Several load-deflection measurements were made on each specimen to give a sufficient number of points to insure the reliability of the curves (Fig. 5).

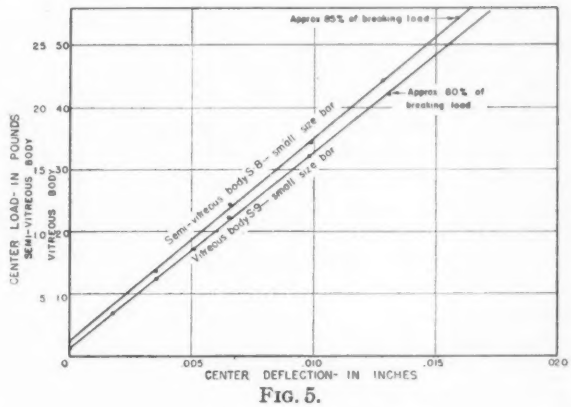

FIG. 5.

IV. Discussion of Results

Tables I and II summarize the results of the modulus comparison by the two methods for the semivitreous and vitreous bodies, respectively. With the improved apparatus and the procedure followed in the test, the values for the moduli by the stress-strain method compare favorably with those obtained by the sonic-vibration method, especially the values for the vitreous bodies. The deviations from the averages within a set of bars, moreover, are much less than those obtained on ceramic and other materials by a less refined stress-strain method.

The correlation between the values by the two methods is not so close with the semivitreous bars as with the vitreous bars. The small bars of body S4 have the greatest difference in values by the two methods, that is, 9.1%; the density of the S4 bars, however, is not so uniform (because they were fired in the laboratory) as the plant-fired bars, and the averages for the S4 bars may therefore be less reliable than those for the plant-fired bars.

The poorer correlation of values by the two methods with all of the semivitreous bars as compared with the vitreous bars might conceivably be due to the fact that semivitreous bodies are inherently less homogeneous in structure because of their porosity than the vitreous bodies. The sonic formula (3) accounts for the bulk

TABLE I

SONIC AND STRESS-STRAIN ELASTIC MODULUS COMPARISON FOR SEMIVITREOUS BODIES

Column (1) body No.; (2) set, specimen size; (3) No. of specimens tested, N; (4) sonic elastic modulus, avg. of N specimens (lb./sq. in. $\times 10^{-6}$); (5) stress-strain elastic modulus, avg. of N specimens (lb./sq. in. $\times 10^{-6}$); (6) and (7) standard deviation of N specimens from set avg., sonic and stress-strain (%), respectively; (8) and (9) max. deviation of any specimen from set avg., sonic and stress-strain (%), respectively; (10) deviation of avg. modulus values for set by the two methods (%); and (11) avg. deviation of modulus by the two methods for individual bars (%).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
S4	Small	12	4.49	4.10	0.9	1.3	2.25	4.1	9.1	9.2
	Medium	12	4.38	4.21	0.9	2.4	1.9	4.3	4.0	4.6
	Large	10	4.24	4.06	0.9	1.6	2.6	4.3	4.3	4.8
S5	Small	12	4.86	4.51	0.7	2.4	1.6	4.6	7.5	7.7
	Medium	11	4.85	4.53	0.4	2.1	0.6	3.8	6.8	6.9
	Large	10	4.96	4.64	0.5	1.0	1.0	1.9	6.7	6.6
S8	Small	12	4.88	4.59	1.4	3.1	2.4	6.2	6.1	6.2
	Medium	12	4.72	4.53	1.4	3.9	2.8	4.8	4.1	4.2
	Large	12	4.72	4.54	0.7	1.0	1.9	1.5	3.9	3.8

TABLE II

SONIC AND STRESS-STRAIN ELASTIC MODULUS COMPARISON FOR VITREOUS BODIES

Column (1) body No.; (2) set, specimen size; (3) No. of specimens tested, N; (4) sonic elastic modulus, avg. of N specimens (lb./sq. in. $\times 10^{-6}$); (5) stress-strain elastic modulus, avg. of N specimens (lb./sq. in. $\times 10^{-6}$); (6) and (7) standard deviation of N specimens from set avg., sonic and stress-strain (%), respectively; (8) and (9) max. deviation of any specimen from set avg., sonic and stress-strain (%), respectively; (10) deviation of avg. modulus values for set by the two methods (%); and (11) avg. deviation of modulus by the two methods for individual bars (%).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
S6	Medium	12	11.1	11.0	0.9	2.2	1.5	4.0	0.90	2.0
	Large	12	11.2	11.2	0.7	1.5	1.4	2.0	0.00	1.3
S7	Small	12	10.3	10.1	0.8	2.3	1.4	4.3	1.96	2.9
	Medium	12	10.0	10.1	0.6	2.1	1.3	3.6	0.99	2.2
	Large	12	10.1	9.98	0.7	2.3	1.3	4.2	1.19	1.9
S9	Small	12	10.9	10.9	0.7	2.2	1.5	3.7	0.00	1.8
	Medium	12	10.9	11.2	0.7	1.7	1.3	3.1	2.71	2.6
	Large	12	11.0	10.9	0.5	1.6	1.2	3.0	0.91	1.7

density of the test bar, but both the sonic and stress-strain methods assume homogeneity of the structure of the bar.

It is planned, in continuing this investigation, to determine the effect of varying the bulk density on the elastic modulus of dinnerware bodies as determined by both methods, which may help to explain the discrepancies noted here. Another possible explanation might be found in the fact that the moduli for the semivitreous bars were quite low, being less than one half those for the vitreous bars. Assuming the same numerical difference in values by the two methods, the percentage difference for the semivitreous bars would then be more than double that for the vitreous bars.

Tables I and II show that the moduli values by the sonic-vibration method agree much better within themselves than do the stress-strain values.

The values for the small-size bars do not agree quite so well as do the medium and large sizes. One explanation for this is that the thickness of the test bar enters the formulas in the second and third power, respectively, and the thinner the bar, the higher the degree of accuracy required in its measurement, especially the unlapped bars which were not uniform in thickness. Another possible explanation is that difficulty was experienced in casting these thin bars solid (slip poured in the end), and although all obviously defective bars were discarded, the bars that were tested may not have had uniform density throughout their cross section.

V. Conclusions

This investigation appears to justify the following conclusions:

(1) The size of the test bar used for the sonic test to obtain the elastic modulus of whiteware bodies is apparently immaterial provided the proper minimum ratio of length to thickness is maintained and if the bar thickness is greater than $^1/_4$ inch. The latter requirement is particularly important for unlapped bars because of the difficulty to obtain a sufficiently accurate average value for the thickness dimension.

(2) It is possible with the refined apparatus and the procedure employed to obtain values for the elastic moduli of vitreous bodies by the stress-strain method which agree well with those obtained by the sonic-vibration method. This agreement is not quite so good for the semivitreous bodies, but definite conclusions regarding the cause of this discrepancy cannot be drawn until the completion of the study of the effect of varying the density on the sonic properties of dinnerware bodies.

(3) There are fewer deviations from the average value for the elastic modulus with the sonic method than with the stress-strain method, and, therefore, fewer specimens should be required for the former method.

(4) The sonic method requires much less time than the stress-strain method, and, in view of its greater accuracy, the sonic method has decided advantages over the stress-strain method.

It is hoped that it will be possible in further investigations of the sonic properties of dinnerware and other ceramic products to develop a nondestructive test of the finished ware.

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AUTOMATIC ENAMELING FURNACE DESIGNED FOR CONTROLLED-OXIDATION FIRING*

By W. G. Martin

Abstract

A unique enamel firing furnace has been designed to make use of the controlled-oxidation firing process. A brief discussion of the problems dictating the design is given, and the special atmosphere generator is described.

I. Introduction

The manufacture of automatic glasslined, hot-water storage heaters has created a number of problems other than those which occur during the development period. The design of a suitable furnace was at the head of this list because it was desired to use the controlled-oxidation firing technique and, as far as could be ascertained, special atmospheres had not been maintained heretofore in furnaces of this size. Starting with the specification of the firing cycle and other conditions to be met, several designs were evolved, and the furnace described here is the result of this study.

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 2, 1941 (Enamel Division). Received May 15, 1941.

II. Description of Furnace

This furnace, which is a roller-hearth type, consists of two chambers in line separated by an automatic, insulated door. The working space is 50 in. wide, and each chamber is approximately 18 ft. long with a maximum working height of 69 in. The butane fuel is burned in alloy tubes that are fired alternately from each side. The tubes extend across the bottom of the furnace, up the opposite side with a 180-degree turn, extending 2 ft. down from the top, and then directly out through the side wall. The combustion mixture is controlled separately for each zone of the furnace and is maintained constant by two hydraulic mixture controllers. The flow of the combustion mixture is controlled by two throttling-type recording potentiometers.

Figure 1 shows side and end views of the furnace, part of the external conveyer, the charging door, and the individual burner stacks; a schematic layout of the furnace is also shown in Fig. 2.

In order to explain the reasons for the design of this furnace, it is necessary to describe the controlled-oxidation method of firing enamel.

III. Controlled-Oxidation Firing

It was found several years ago that the amount of oxidation of the iron base could be controlled readily by heating the ware for a suitable length of time approximately to 1000°F. in an air atmosphere. This treatment produces a layer of iron oxide on the enameling iron underneath the dry enamel. More or less of this oxide layer, of course, is formed in any standard sheet-steel enameling operation. After the desired amount of oxide has been formed, the firing operation is completed in a nonoxidizing atmosphere.

(1) Advantages

The advantages of the controlled-oxidation process are (1) copperhead formation is practically eliminated because of the lack of oxygen at the fusing temperatures; (2) the formation of fish scale can be definitely retarded (the more recent concepts of the conditions that promote fish scaling tie in quite well with the observed results of this process); and (3) because enamel is not applied to the exterior of the product made by this company, the process is valuable in holding down the scale formation; this advantage also applies to the areas which are subsequently welded.

The method of controlled oxidation has been practiced for a number of years in the manufacture of large glasslined vessels. These vessels, which are entirely enclosed except for a few openings and which may be covered, act as their own muffle, and the atmosphere in the vessels can be handled independently of the atmosphere in the firing furnace. When it was decided to go into production on glasslined, hot-water heater tanks, a new problem arose because the design of these tanks is based on enameling the cylinders and heads separately; the assembly is made after enameling. A design was necessary, therefore, that would permit the control of the atmosphere in the entire furnace.

This problem had been given casual consideration occasionally, and it was thought that an inclined hump-type furnace might be suitable. The ware would be oxidized while it traveled up the incline of the hump, and the chain speed was regulated so as to permit satisfactory oxidation by the time the ware reached the hot zone of the furnace. A nonoxidizing atmosphere would be maintained in the hot zone at the highest elevation of the furnace. Furnace manufacturers who

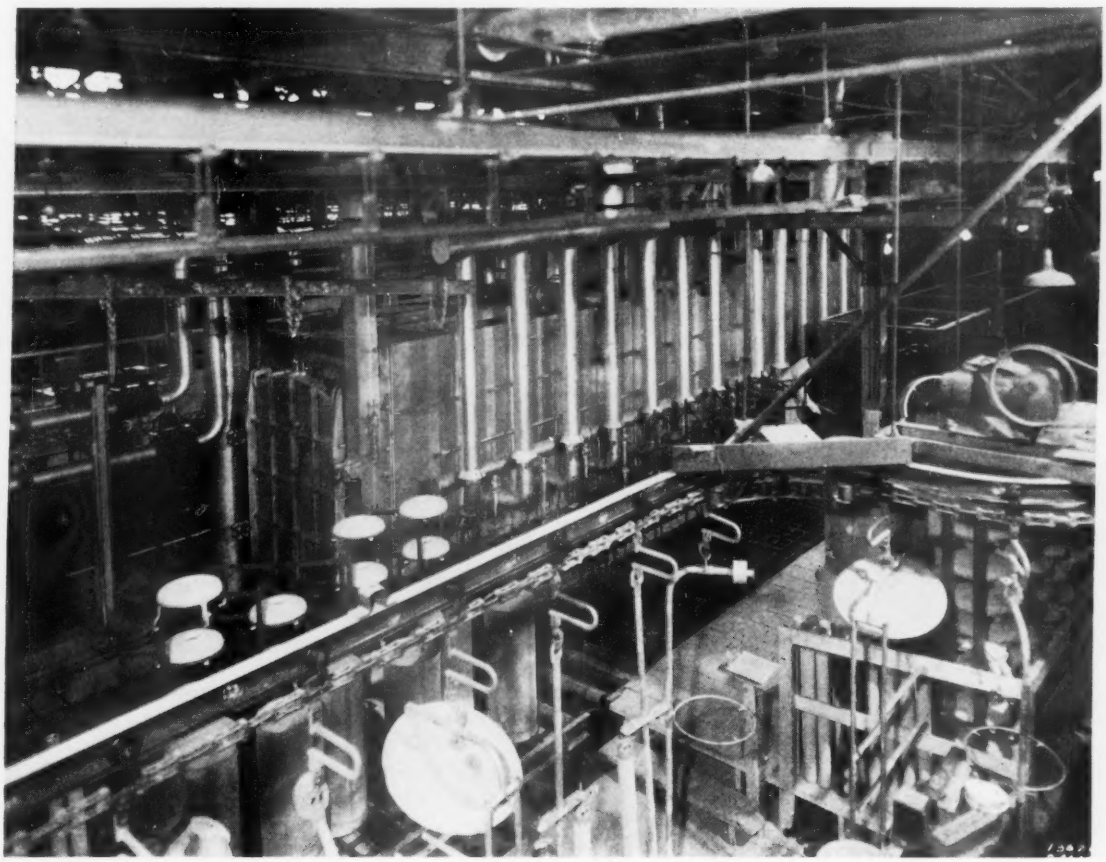

FIG. 1.—Enameling furnace.

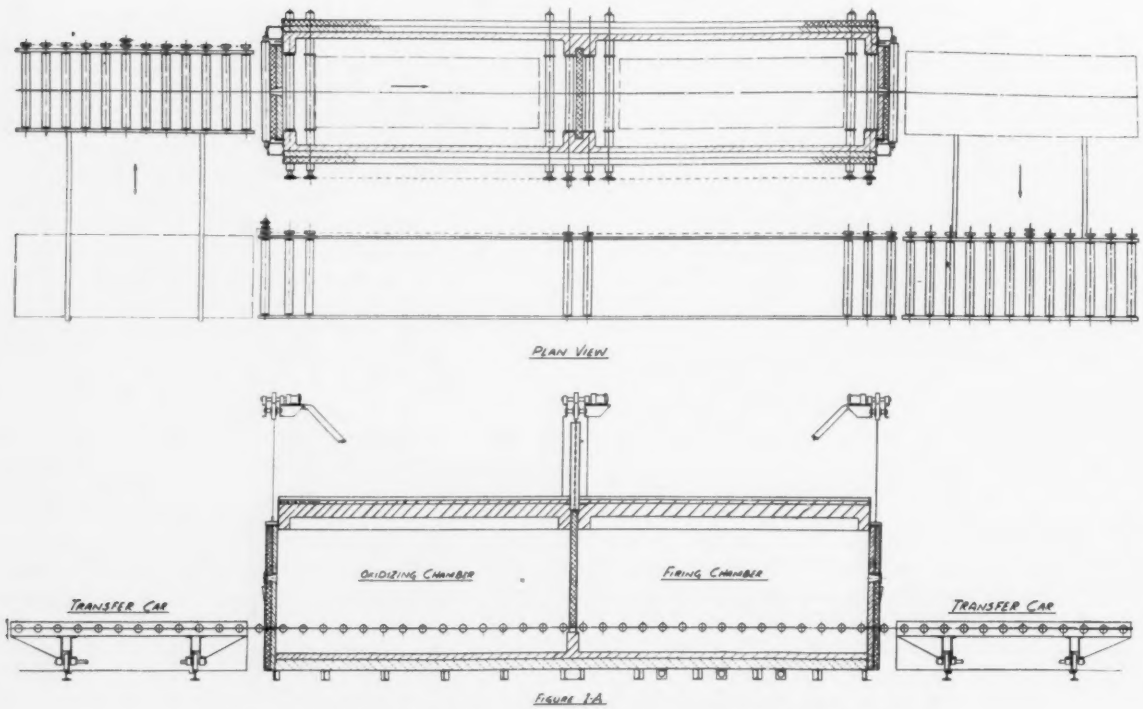

FIG. 2.—Plan and elevation of furnace for controlled-oxidation process.

were consulted thought that there was insufficient experience available for use as a basis for computing this type of design, and it was feared that the furnace might have either too much or not enough gas in the hot zone. Further study indicated definitely the necessity of closing the oxidizing and the inert atmosphere chambers except when the ware was moving. Even then there was some doubt as to whether the oxygen could be kept out of the hot zone. Data were available from the operations on enameling large glasslined vessels as well as from the laboratory furnace.

IV. Atmosphere Supply

The problem was then approached from another angle. On the conservative assumption that inert atmosphere introduced into the hot zone would mix completely with the air therein, an amount of gas equivalent to the volume of the furnace should reduce the oxygen content from 20 to 10%. Similar amounts of gas should successively cut the remaining oxygen content in half, and four volumes of gas would therefore reduce the oxygen content to $1^1/_4$%. Because the purging gas can readily be made slightly reducing in analysis, it was assumed that the remaining oxygen would be consumed by the carbon dioxide and hydrogen. For the purpose of calculations, 1 cu. ft. of purging gas at room temperature was assumed to expand approximately to 4 cu. ft. at 1600°F.

This method of calculating the requirements of the purging gas is conservative because, by introducing the cool purging gas at several points in the bottom of the furnace and by providing outlets at the top of the chamber, it is possible to move out much of the air without mixing with the purging gas; therefore, less purging medium is necessary. It was possible to supply an average of 250 to 300 cu. ft. per minute; actually, 175 cu. ft. per minute are generated, and this is used to supply 450 cu. ft. per minute for the first minute, and 140 cu. ft. per minute for the remaining 11 minutes of a nominal cycle.

In the manufacture of large vessels, it had been the practice to make the necessary nonoxidizing atmosphere by burning butane in a suitable combustion chamber. It was known, however, that internal combustion engines were in use in this country to create nonoxidizing atmospheres and, for this particular problem, it seemed that the use of an engine would have several advantages.

Figure 3 is a view of the engine used to supply the atmosphere for the fusing zone of the furnace. The low-pressure scrubbers are on the right; the high-pressure scrubbers, on the left; and the gas receiver may be seen overhead. Because of surrounding machinery, the compressors, located behind the scrubbers on each side of the engine, are not visible.

The butane gas is drawn into a standard industrial type, 6-cylinder 120-h.p. internal combustion engine. The bore and stroke of the engine were chosen so that a sufficient volume of gases would be formed at 900 r.p.m. The exhaust gases are led through two water-spray chambers principally to cool them before they are introduced into the compressor. The entry of the gases is controlled by a diaphragm valve so that the compressor, which has somewhat more capacity than the engine, will not cause a vacuum in the exhaust system of the engine. The compressor drives the gas into

another water-spray system, which is maintained at 125 lb. per sq. in.

V. Advantages of Compressed Gas

The use of high pressure has two advantages as follows: (1) The gases, compressed to 125 lb. per sq. in. and cooled to 70°F., will lose as much moisture as though they were cooled to 14°F. at atmospheric pressure; this permits drying the gas without the use of such special equipment as refrigeration or absorption driers. (2) The gas generator may run at a constant rate to supply a receiver tank from which the gas can be drawn readily at a varying rate. It is necessary, furthermore, to provide a load for the engine in order to realize the theoretical volumetric performance; in fact, a second compressor, which is a duplicate of the gas compressor, is driven by the engine in order to provide the necessary load. This compressor delivers air into the shop lines approximately at the rate of 200 cu. ft. per minute. This method is most satisfactory because the compressed air is obtained at no extra cost and represents a definite saving.

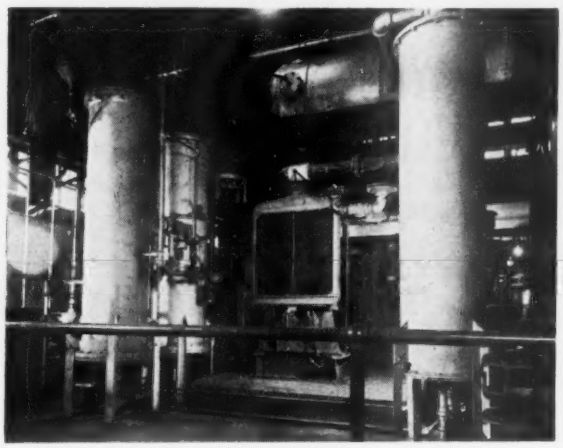

FIG. 3.—Inert gas producer.

Flexibility of the capacity of the gas system was obtained by specifying an engine large enough to produce the maximum calculated amount of exhaust gas at fairly high operating speeds, about 1400 r.p.m. The engine, however, is operated at 900 r.p.m., which is at the low end of the practical speed range where maintenance is at a minimum. The actual operation figures have checked the calculations very well, and it has been found that the hot zone can be purged in 55 seconds.

An operating feature of the furnace is a control which causes the roller hearth to move the load slowly back and forth in each chamber during the time set up on the automatic timers. This control consists of four electric eyes with their beams placed across the ends of each chamber, and it is tied in with the control of the furnace. The moving load of ware interrupts the light beams and thus controls the roller-hearth drive. An automatic electric timer for each chamber is so interconnected with the electric eyes that, when the cycle has been started, the alloy-firing trays continue to advance automatically around the system. The movements of the furnace doors, alloy trays, and roller units are accomplished by means of a series of interlocked relays, a number of which are of the latching type.

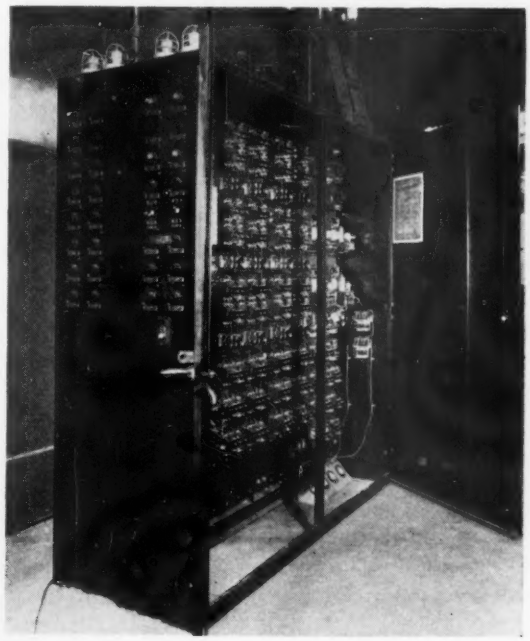

FIG. 4.—Control panel.

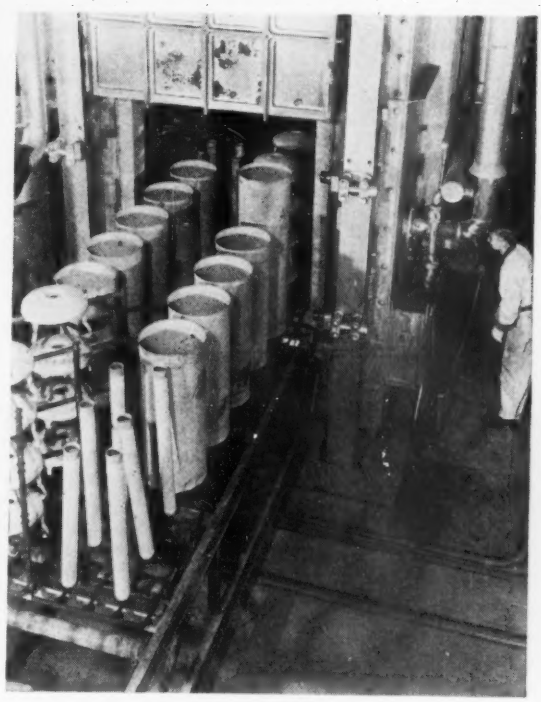

FIG. 5.—Load entering furnace.

The control panel, Fig. 4, shows the various relays, timers, and electric-eye circuits which cause any desired furnace cycle to repeat continuously.

Five alloy trays, 4 ft. wide and 14 ft. long, are used for the transportation of the ware through the furnace. The roller-conveyer system outside the furnace can hold four trays and the furnace, two trays, and thus there is always a place in the system for a tray to advance. One tray must be removed from the conveyer when the furnace is idling in order to empty the furnace so that the rolls may be kept in motion. Figure 5 shows a loaded tray moving from the transfer car into the oxidizing chamber of the furnace.

VI. Operation of Furnace

While the furnace is in normal operation, the sequence is as follows: The transfer car carries the tray over to the furnace while the door is rising. As soon as the door reaches the top limit switch, the rolls turn and advance the load into the furnace. When the load crosses the second light beam near the center of the furnace, the door closes, the transfer car returns, and the load begins to oscillate. All of the trays advance as soon as the transfer car returns to the conveyer line, which places an empty tray in the loading station. While the load is oxidizing, a fired load is discharged onto the empty transfer car at the other end of the furnace. The oxidizing temperature is controlled so that the proper amount of time will elapse shortly after the hot zone is empty. When this happens, the center door rises, and the load advances into the hot zone. On intersecting the last light beam, the center door is closed again, and the gas flow is stepped up to the purging rate. An auxiliary timer is started, which will cut off the high flow of purging gas after about one minute. When the center door reaches the full closed position, the first door begins to open to receive another load of ware. The following sequences will clear the second transfer car so that it will be empty by the time the load is fired, as determined by an automatic reset electric timer. Inasmuch as there is a station between the second transfer car and the unloading station, the ware cools down fairly well by the time that it must be handled.

This furnace has been designed for a gross load of 10,000 lb. per hr. with a tool-ware ratio of 1 to 2. The fuel consumption is approximately 55 gallons of butane per hour under full load conditions.

The ordinary range of the metal thickness of the product is quite wide, varying from 0.100, or about $^{3}/_{32}$ in., to 0.312, or $^{5}/_{16}$ in. The firing time must be changed to cover such a range properly, but the uniformity of temperature throughout each chamber is very good, so that there is no difficulty in firing on the same load that part of the thickness range involved in any one model of tank.

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CHANGES OCCURRING IN A CLEANER BATH DURING USE*

By J. M. Zander

Abstract

An investigation was undertaken to discover some of the changes that occur in an alkaline cleaner bath while it is being used. The effect of cleaning the ware over a period of time was studied to determine the properties of a cleaner bath, such as pH, specific gravity, insolubles, and total solids, and the possible correlation of these changes with respect to cleaner bath "performance." Data are presented which indicate a change in the initial properties of the cleaner-bath solution, but the trend of these changes is not necessarily progressive in the same direction. A close analysis of the curves and photograph showing the changes in properties reveals a common point that probably signifies a pronounced change in the cleaning ability of a cleaner-bath solution.

I. Introduction

The treatment of metal surfaces preparatory to enameling is a fundamental process of the enameling industry. For the past two decades, ware has been cleaned by immersion in a hot or boiling solution that is charged with an alkali cleaner compound and by rinsing. Successful cleaning involves the saponification of fats and vegetable oils into soap and the emulsification of mineral oils and greases into minute globules, which are dispersed throughout the cleaner solution, plus the principles of wetting power, detergency, saturation, surface tension, and rinsability. The reactions and resulting changes which occur in cleaning are complex. It is unquestionably the combined influence of these various changes that determines the quality of the final cleaning job attained at any time from an alkaline cleaner bath, irrespective of the chemical composition of the cleaner compound employed in making up the cleaner solution.

All too often the cost of cleaning is based on the number of square feet of ware cleaned rather than on the number of square feet of enameled ware that is finished satisfactorily. Because a low cleaning cost is important

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 1, 1941 (Enamel Division). Received April 2, 1941; revised copy received August 22, 1941.

FIG. 1.—Weekly changes in settling properties of the insolubles after standing 40 minutes.

in the vitreous enameling industry, there has been a tendency on the part of enamelers to prolong the life of a cleaner bath and to disregard the relation that exists between the cleaning phase and the subsequent pickling and enameling operations. It is true that metal surfaces which have been cleaned by the present cleaning practices may be enameled with a fair degree of success, but this does not preclude the possibility that the number of rejects or "re-ops" cannot be decreased by doing a better job of metal cleaning.

It is common practice in enameling plants to operate a cleaner bath at a definite Na_2O content on the assumption that the Na_2O content is a measure of the cleaning ability of the cleaner bath. The latter is not true because a cleaner bath will reach a state where it will no longer clean ware satisfactorily even though the Na_2O content may be up to standard.

In view of these facts, a study was made of some of the physical and chemical changes that occur in a cleaner bath during its use.

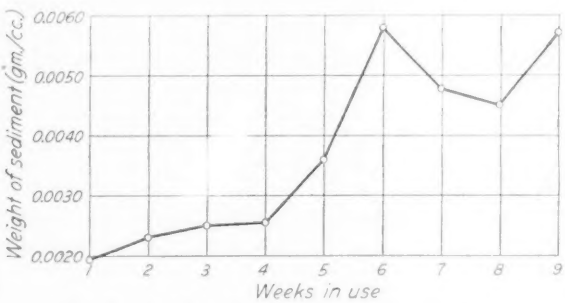

FIG. 2.—Weekly changes in sediment content.

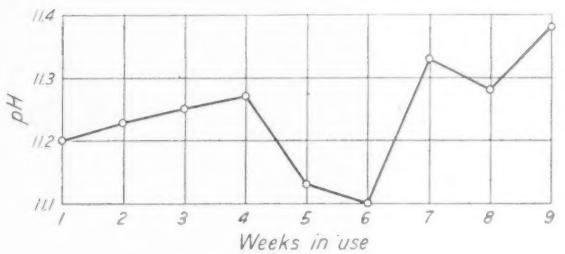

FIG. 3.—Weekly changes in pH.

II. Test Data

(1) Collection of Samples

A sample was taken from the cleaner tank under test, which will be called bath (A), after each week of operation for a period of nine weeks. The cleaner bath at the end of this period no longer seemed to do a suitable job of cleaning. This tank had a capacity of 1500 gallons to which 800 lb. of cleaner were added as the initial charge. From 5000 to 20,000 sq. ft. of ware were cleaned per week. Inasmuch as the tank was operating in a jobbing shop, various drawing compounds and oils were encountered in the cleaning operation. The Na_2O content of the nine samples varied over a range of $4 \pm 0.1\%$.

(2) Properties

(*A*) *Appearance of Samples:* A visual inspection of the thoroughly agitated sample solutions after standing revealed an apparent increase in the amount of sediment with each week the bath was in use until the sixth week; a gradual change also occurred from a flocculant form at the start to a curdy and granular form. Figure 1 furnishes a comparative idea of the amount and settling properties of the insolubles after standing for 40 minutes.

(*B*) *Insolubles:* Figure 2 shows the actual weight of the sediment present in each sample. This test was made by filtering 20-cc. portions of the agitated sample solutions through porcelain crucibles with a molded porous vitreous filtering medium without subsequent washing to avoid possible losses and by drying for 18 hours at 105°C. in a constant temperature oven. There was no attempt to make a quantitative determination of the composition of these residues, but qualitative analyses indicated the presence of soap, carbonate, calcium, and iron.

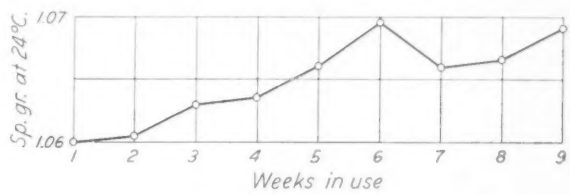

FIG. 4.—Weekly changes in specific gravity.

(*C*) *pH Concentration:* The pH of the sample solutions was determined with a Beckman pH meter, and the values obtained are shown on Fig. 3.

(*D*) *Specific Gravity:* Specific gravities of the test solutions are given in Fig. 4 and were made on the agitated sample solutions by the pycnometer method.

(*E*) *Total Solid Residues:* A 10-cc. portion from the agitated samples and another 10-cc. portion from the supernatant liquids were evaporated to dryness and ignited. The weights of these residues are shown in Fig. 5.

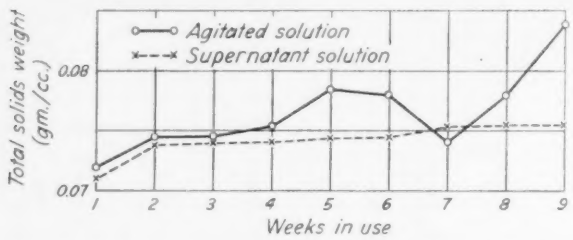

FIG. 5.—Weekly changes in total solids after ignition.

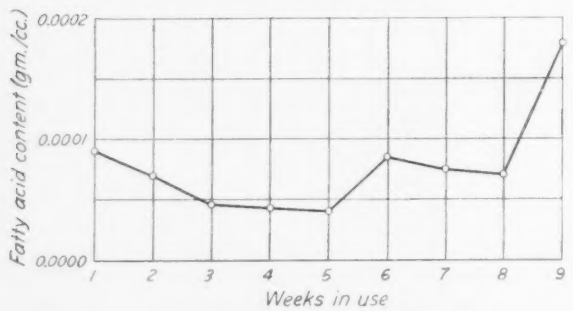

FIG. 6.—Weekly changes in fatty acid content.

(*F*) *Soap Content:* The soap content of the cleaner bath was determined by acidifying a 25-cc. portion of sample cleaner solutions with sulfuric acid, and the fatty acid was extracted by shaking in a separatory funnel with several 40-cc. portions of ether. The ether layers were pipetted off, and the combined ether extractions in each case were evaporated on a water bath in a weighed Soxhlet flask. Figure 6 shows the weight of fatty acid obtained from the agitated solutions.

III. Cleaner Bath Performance

Because the percentage of Na_2O in the bath is approximately the same at the start as at the finish, regardless of its composition, it seems that the amount of cleaner compound added as the initial charge in the tank should not be considered in evaluating the cleaner performance. The use of cleaner additions alone in calculating the cleaner performance produces a curve with a rather indefinite trend as shown by the solid line (*A*) on Fig. 7; this figure also shows the performance curve (*B*) of another bath of same volume (1500 gal.) which was charged with the same cleaner compound. The performance curves of the baths in both cases leveled off after about 1000 lb. of cleaner compound additions had been made and approximately 85,000 sq. ft. of ware had been cleaned. This point occurred after six weeks of use in bath (A), which was under test; in the case of (B), this change took place in three weeks.

In order to learn whether this leveling off of the performance curve was significant, a series of curves was plotted in the same manner on a number of cleaner baths of similar composition, using shop control data. These baths also had a volume of 1500 gallons as shown in Fig. 7. Figure 8 shows that the trend of the performance curve of all of the tanks under consideration leveled off after about 1000 pounds of cleaner additions were made.

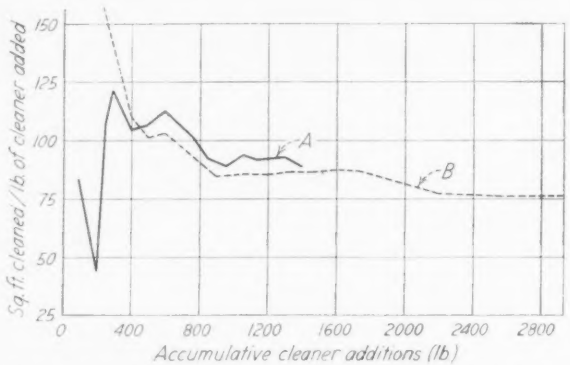

FIG. 7.—Performance curves of two cleaner baths of the same composition based only on cleaner additions.

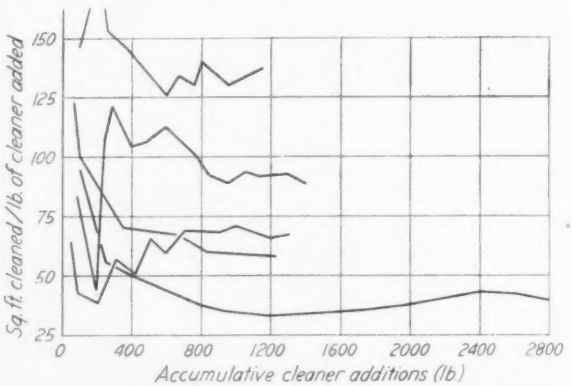

FIG. 8.—Performance curves of cleaner baths of different compositions based only on cleaner additions.

The curves of Fig. 7 indicate that, in maintaining the cleaner at a definite Na_2O content, the square feet of ware cleaned per pound of cleaner compound added steadily decreases with the life of the tank. In the case of the two tanks tested, the decrease in cleaner performance as shown by curve (*B*) was so great that the cost of cleaning ware throughout the life of both tanks was about the same even though the weight of cleaner compound used to charge the tanks initially is included. As no advantage was secured by the greater footage that passed through tank (B) compared with tank (A), it would have been just as economical to have dumped this tank after 125,000 sq. ft. had been cleaned

and to have started a fresh tank with the probability of securing a better cleaning job with decreased risk of enameling difficulties.

IV. Discussion of Results

A study of the data presented in these tests indicates that some pronounced change took place in the cleaning bath under test after 1000 pounds of cleaner had been added to the initially charged tank, which roughly corresponds to the six weeks of use shown in Figs. 1 to 6. This change raises the question as to whether the observations noted may be interpreted as being the point at which this particular cleaner bath had lost part of its original cleaning ability and should have been discarded. This fact unfortunately cannot be proved definitely at this time because no positive tests are available to ascertain when a piece of ware is clean other than to observe the presence of waterbreaks on the ware during the pickling operation or to note the quality of the enamel finish. Inasmuch as it was possible to clean only about 40,000 sq. ft. more ware after this point was reached, some significance must be attached to this point, which was determined by the experimental data obtained from this study.

These data are presented with the idea that they possibly offer a new approach in ascertaining the state of the cleansing ability of a cleaner bath or the point at which this bath should be discarded. It does seem to be more than a coincidence that these tests should show a definite change in the properties of the cleaner bath after approximately the same amount of use.

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INSULATING FIREBRICK FOR KILN CONSTRUCTION*

BY J. D. MCCULLOUGH

ABSTRACT

The use of insulating firebrick directly exposed to the furnace gases in the construction of kilns for firing brick and tile is discussed. Owing to the small amount of heat stored in and conducted through these firebrick, the length of the firing cycle may be reduced and substantial fuel savings may be effected.

I. Introduction

Insulating firebrick is a term applied to a group of lightweight refractories that possess definite insulating characteristics but are also suitable for direct exposure to furnace gases in the combustion zone. Their density varies from 19 to 62 lb. per cu. ft., corresponding approximately to 1.1 to 3.65 lb. per 9-in. straight. They are classified into several temperature groups from 1600° to 3000°F. according to their resistance against shrinkage.

II. Production of Insulating Brick

Insulating firebrick are usually made from the same type of refractory clays used in regular firebrick. The light weight is obtained by porosifying the structure. Two principal methods are used to produce these brick as follows: (1) finely divided carbonaceous material, such as wood or cork, is mixed with the clay and is burned out during the firing process; the voids left by the burned-out particles produce the porosity; and (2) air or gas bubbles are produced in a fire-clay slurry by mechanical agitation or by chemical means, and the resulting porosity during the drying and firing cycles is retained by suitable manufacturing methods.

It is the general practice to grind insulating firebrick to size after firing, and closer tolerances therefore may be maintained than are usually possible with firebrick which are fired to size.

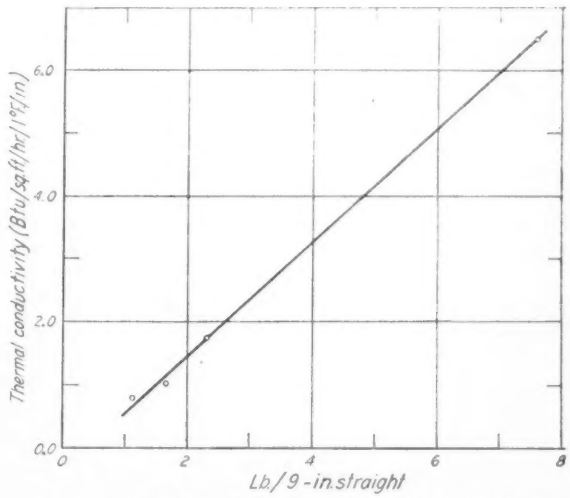

FIG. 1.—Relation between weight and thermal conductivity for several brands of kaolin base refractories (mean temp., 900°F.).

III. Characteristics of Insulating Brick

A rough guide for determining the comparative thermal conductivities of refractories in the lower temperature ranges is by their weight. The heavier the brick the less will be its insulating value. Figure 1

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* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 1, 1941 (Refractories Division). Received June 26, 1941.

shows how the conductivity increases with weight for a group of kaolin base refractories at a mean temperature of 900°F. The pore size assumes increasing importance in the higher temperature ranges, and of two brick having the same weight, the one with a finer pore structure will have the lower conductivity.

Because insulating firebrick weigh less than regular firebrick, they have a lower heat-storage value than the latter, which means that a smaller amount of fuel is required to bring them up to furnace temperature. The total B.t.u.-storage value is the product of the temperature rise multiplied by the specific heat multiplied by the weight. As the principal variable of this equation is weight, it is apparent that the heat storage of refractories is closely proportional to weight.

Because these porous brick conduct and store less heat than firebrick, they permit quicker heating of furnaces which are lined with them, and for the same reason they require less fuel.

The effect of these properties on heating time and fuel consumption of furnaces lined with insulating brick is shown in Fig. 2. Two furnaces, identical in size, burner equipment, and all other respects except for the type of lining, were heated empty, and the following results were obtained:

	No. 1 furnace (insulating) firebrick)	No. 2 furnace (firebrick)
Time to reach 2000°F. (hr., min.)	1, 25	4, 30
Gas required to reach 2000°F. (cu. ft.)	350	1130
Relative weight of brick forming lining	0.30	1.0
Relative fuel input	0.31	1.0
Relative time to reach 2000°F.	0.31	1.0

The furnaces in this particular test were shut off within 30 minutes after the No. 2 furnace reached 2000°F., thus giving no data on the holding consumption. Other tests with these same furnaces showed that the No. 1 furnace could be held at 2000°F. with 113 cu. ft. of gas per hr. as against 200 cu. ft. per hr. for furnace No. 2. The curves emphasize how greatly the fuel consumption and heating time are affected by decreasing the weight of the lining. It is particularly interesting to note that although the heavy firebrick wall was insulated, the insulation apparently did not improve the fuel consumption or heating time of the firebrick furnace while it was in the unsteady state.

Another characteristic of insulating firebrick, if operating conditions so require it, is that they may be cooled rapidly by admitting cold air to the furnace because the relatively low heat storage requires that less heat be removed from the furnace lining.

Uniformity of heating is also a desirable characteristic of these brick. If one part of the furnace tends to heat faster than another part, the difference in thermal heats will result in a transfer of heat by radiation. Because of the low weight of the brick, a comparatively small transfer of heat will allow the temperature balance to be restored. Furnaces lined with insulating firebrick respond quickly to temperature adjustments for the same reason. This is particularly valuable for continuous furnaces such as tunnel kilns.

An unusual feature of these brick is that they may be cut and drilled with ordinary woodworking tools. This frequently eliminates the use of special shapes as the brick can be shaped in the field to suit conditions; it also eliminates the time delay involved in making molds and firing special shapes.

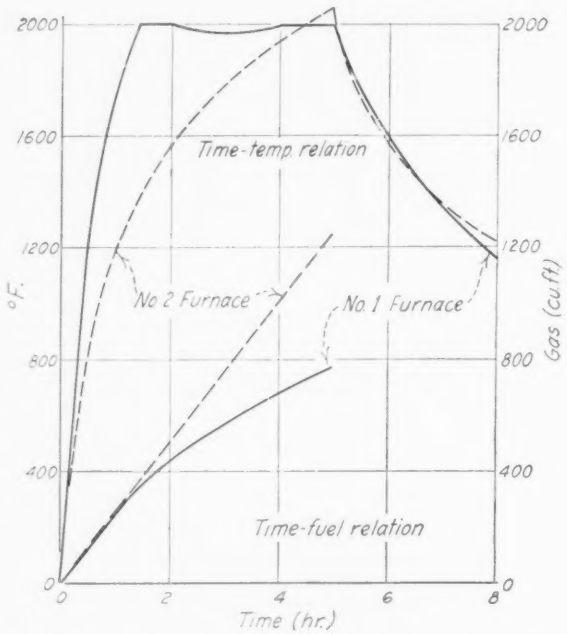

FIG. 2.—Comparative heating time and fuel requirements of two empty furnaces lined as shown; No. 1 furnace: $4\frac{1}{2}$-in., $2\frac{1}{4}$-lb. insulating firebrick and $2\frac{1}{2}$-in., 2-lb. insulating firebrick; No. 2 furnace: $4\frac{1}{2}$-in., $7\frac{1}{2}$-lb. firebrick and $2\frac{1}{2}$-in., $2\frac{1}{2}$-lb. insulating firebrick.

IV. Limitations of Insulating Firebrick

Insulating firebrick are not suitable for locations where they are subjected to physical punishment, such as being struck with firing tools or heavy implements, because they are damaged more readily than a heavy brick. They are not usually recommended for locations where they will come in contact with molten slag. Their porosity in this case causes them to absorb the slag rapidly, which results in a progressive sloughing off of the surface. They have been used successfully, however, in oil-fired furnaces where slagging is definite but not severe. The exposed surface in these installations is frequently protected by a thin wash coating of a chrome base mortar.

Insulating firebrick do not have so high a resistance to erosion as heavy firebrick when they are subjected to dust, ash, or other particles in a gas stream moving at high velocities. This shortcoming frequently may be overcome by the use of a suitable coating material on the exposed surface to improve the resistance against abrasion. With this protection, insulating firebrick have been widely used for the past eight years in the upper side walls of large boilers fired with pulverized coal, where the gas carries large quantities of abrasive fly ash.

V. Application of Insulating Firebrick

Because of their many advantages, insulating firebrick are widely used in furnaces for heat-treating, forging, annealing, normalizing, and stress relieving in the metals working field. They are also used in many types of chemical furnaces, oil stills and heaters, boiler furnaces, and similar combustion units. Only those applications, however, which are closely connected with ceramic kilns will be discussed at this time.

(1) Periodic Kiln

About five years ago, a refractories manufacturer installed a periodic kiln, which was approximately 22 ft. in inside diameter with 13½-in. insulating-firebrick walls backed up with 2 in. of supplementary insulation and a 9-in. insulating-firebrick crown. The ware was fired at temperatures in excess of 2700°F. (the insulating firebrick selected for the kiln were suitable for temperatures to 2800°F.). The fuel was natural gas. Earlier periodic kilns at this plant constructed of heavy firebrick were rectangular and fired with coal.

The results indicated that the complete firing cycle was shortened and that the total fuel cost per ton of ware with natural gas (at about 45¢ per million B.t.u.) was about the same as with the coal-fired, firebrick-lined kilns. With the wide discrepancy in price existing between coal and natural gas, this is a noteworthy record. The features that contributed to the result were (1) better thermal efficiency obtained with natural gas than with hand-fired coal, (2) improved design of the kiln, and (3) use of insulating firebrick. The importance attributed to insulating firebrick is indicated by the construction of four additional kilns of the same material since the original installation.

(2) Rectangular Kiln

Figure 3 shows a rectangular kiln 25 ft. long, 17 ft., 6 in. wide, 5 ft., 6 in. high to the skewline, and 2 in. per ft. of span in the rise of the arch. This kiln, lined with insulating firebrick capable of withstanding 2800°F., was built to fire glass tank blocks at temperatures of 2700°F. and higher. The operating results have been extremely satisfactory, although its efficiency could not be compared with heavy firebrick kilns because there were none of this type in the same plant. Several other kilns, however, in which insulating firebrick were used, have since been built by the same manufacturer.

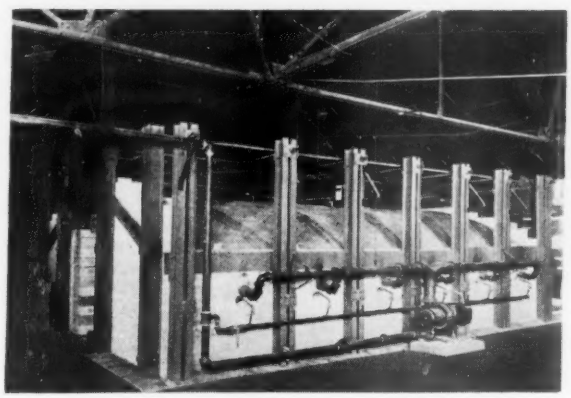

FIG. 3.—High-temperature ceramic kiln lined with insulating firebrick.

(3) Gas-Fired Kilns

Two kilns for firing refractory ware that were converted from coal firing to natural gas were 9 ft. inside diameter and 7 ft. high from the floor to the spring line of the crown with 18-in. firebrick walls and crowns. The firebrick setting was retained throughout in one of these kilns, but the dome of the second kiln was constructed of a 2600°F. insulating firebrick. The upper part of the second kiln heated up so much more rapidly than that of the first kiln that the bag walls could be completely eliminated; the kiln setting was opened at the bottom, and luminous flame burners were fired directly into the center of the kiln, which resulted in uniform temperature distribution over the entire height of the kiln. On certain types of ware, a reduction of one third the firing time has been obtained in a firing cycle that ordinarily requires 72 hours.

(4) Circle System Firing

An interesting and unusual application of insulating firebrick to kilns for firing common brick is found in the Circle system of firing.[1] A series of kilns, mounted on a circular track, move periodically over the ware, which is set on stationary kiln floors. The entire lining of the kilns or hoods is made of 9-in. or 4½-in. insulating firebrick, depending on the location; the roofs are formed of flat suspended arches, made from standard 9-in. straights. The low weight, low heat storage, and high insulating qualities of these lightweight refractories have made them extremely satisfactory for this application.

(5) Kiln for Brick and Tile

A kiln for firing common brick and tile, which was 36 ft. in diameter with 10 fire mouths (coal-fired), was rebuilt with insulating firebrick. The walls originally were built of 24-in. red brick and the crown of 8-in. red brick. About four years ago, a 4½-in. veneer of 2000°F. insulating firebrick, weighing 1.75 lb. per 9-in. straight, was installed inside the existing wall; the crown was rebuilt with 9 in. of the same type of insulating firebrick, and a 2½-in. course of insulating firebrick (a total of 11½ in.) laid flat on the top. The crown had 9 in. of firebrick for 3 ft. from the skew line so that the portion over the bag walls would be protected from the effect of the coal ash and slag which it was thought might have a detrimental effect on the lighter weight brick. The firebrick were covered with 4½-in. insulating brick, and the entire crown was coated on top with a waterproofing material inasmuch as the kiln was located out of doors.

The results have indicated a definite reduction of time in the firing and cooling cycle, and the fuel consumption has been decreased approximately 25%. A

[1] J. D. McCullough and G. M. Frederick, "Use and Advantages of Insulating Firebrick in the Circle System," *Bull. Amer. Ceram. Soc.*, **19** [1] 16–19 (1940).

recent inspection of the wall and crown indicated that the brick are in excellent condition although they have been in use for almost four years. The experience with this kiln also showed that insulating firebrick could have been used for the entire crown instead of the firebrick over the bag walls.

Insulating firebrick have been used in other kilns for firing red brick and tile, but data on the operating results have not been released.

(6) Periodic Kilns in England

Allen[2] has presented complete data on insulating firebrick for lining periodic kilns in the results on two kilns of the same size and capacity. The first kiln was lined throughout with heavy firebrick; the second kiln employed insulating firebrick in the side walls, starting at the top of the bag walls for the inner 9 in. of a $23^1/_2$-in. wall as well as for the entire dome. The firing and cooling time for the second kiln was reduced to 170 hours from the 192 hours required for the firebrick kiln. The fuel consumption was also reduced approximately 21%. Increased savings were obtained later by using insulating firebrick for the dome and entire side-wall height and by modifying the kiln design to obtain the maximum efficiency of insulating firebrick.

VI. Effect of Heat Storage and Heat Flow Through Walls and Arches

A considerable amount of data has been published as tables or curves on the heat-flow and heat-storage characteristics of various thicknesses of firebrick and insulating firebrick, used alone or in different combinations. When such data are applied to a specific problem, they usually refer to a wall that is in thermal equilibrium (completely saturated with heat) so that the heat flow is constant and there is no further absorption of heat by the brick itself. These data are valuable and may be applied directly to a furnace which operates continuously at a constant temperature. For furnaces, however, that are subjected to alternate periods of heating and cooling, some modification of the heat flow and heat storage must be made to determine their variable effect.

Some useful constants have been developed for intermittent furnaces which are started up each morning and shut down each night,[3] but few data are available on cycles comparable to those used in the ceramic industry where long, slow firing and cooling periods are necessary.

The calculations for studying a wall, which is in the unsteady state while it is being brought up to equilibrium temperature, may be performed by Schmidt's method. This method of analysis may be performed graphically[3] or analytically[4] (the latter method was used to develop the accompanying curves).

[2] H. V. Allen, "Hot-Face Insulation," *Trans. Ceram. Soc.* [England], **35** [10] 437–68 (1936); *Ceram. Abs.*, **17** [1] 19 (1938).

[3] W. Trinks, Industrial Furnaces, Vol. I, 3d ed., p. 96 ff. John Wiley & Sons, Inc., New York, N. Y., 1934. 456 pp.

[4] A. Schack, H. Goldschmidt, and E. Partridge, Industrial Heat Transfer, p. 305 ff. John Wiley & Sons, Inc., New York, N. Y., 1933. 371 pp.

The temperature gradient through the wall was determined for periodic intervals, and the heat storage was obtained by multiplying (*a*), the weight of the brick, by (*b*), the mean temperature rise above 80°F., by (*c*), the specific heat corresponding to the mean temperature.

The heat flow was obtained by means of well-defined relationships existing between the transfer of heat from a plane wall to a surrounding gas at a lower temperature. The surrounding medium in this case was assumed to be still air at 80°F.; when the calculations showed the outside of the wall to be above 80°F., the heat flow was taken at the rate corresponding to the average outside wall temperature at the beginning and end of each time interval.

The following cycle, selected for study, was used to fire red brick made from a Maryland clay:

Firing cycle	
Hr.	°F.
24	80– 600
24	600–1000
18	1000–1800
6	1800–1850
6	At 1850

This cycle may be somewhat shorter than is generally employed, but it is a satisfactory illustration.

Figure 4 shows the heat input from a cold start into a kiln crown that has 9 in. of firebrick plus 2 in. of red brick or a total thickness of 11 in. The density of these materials was taken as 125 lb. per cu. ft., corresponding to 7.5 lb. for a 9-in. straight firebrick.

The heat flow through the brick and the heat storage of the brick are plotted (*a*) separately to show their relative influence and (*b*) as a combined sum to give the total cumulative input.

The heat flow does not commence until some time after the start of the cycle because it takes the heat a certain period of time to travel through the wall and to cause an increase in the temperature of the outside wall. The amount of time required increases with increasing wall thicknesses. After the heat flow is established, it grows rapidly for this cycle. If the final soaking period at 1850°F. were held long enough, the curve of the heat flow would straighten until it would become a horizontal line, which would indicate that the brick were absorbing no more heat.

The heat-storage curve presents several interesting points. For the first 24 hr., the average heating rate (for purposes of calculation) was approximately 22°F. per hr., and for the second 24 hr., it was about 17°F. per hr.; thus at the end of 24 hr., there is a break in the curve because the rate of the input decreases. At this point, because of the lag in temperature distribution in the wall plus the constant increase of the hot face temperature, the wall has reached only 77% of equilibrium. For the next 13 hr., owing to the slower heating rate, the equilibrium gradually increases to 88%. Beyond this point, the increase in percentage of equilibrium stops and the result is a lower rate of input and a break in the curve. Near the end of the cycle where the temperature levels off in the range of 1800° to 1850°F.,

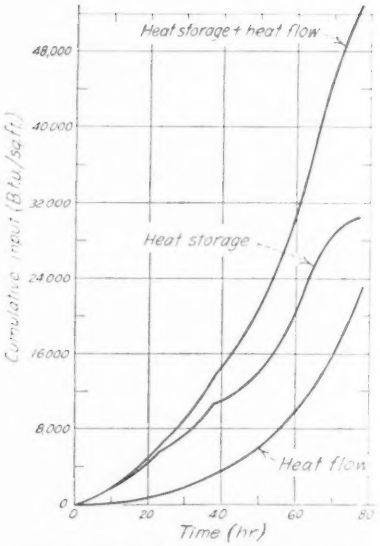

FIG. 4.—Heating curve: 11-in. heavy brick crown. Heating cycle: 24 hr., 80°–600°F.; 24 hr., 600°–1000°F.; 18 hr., 1000°–1800°F.; 6 hr., 1800°–1850°F.; 6-hr. soak at 1850°F.

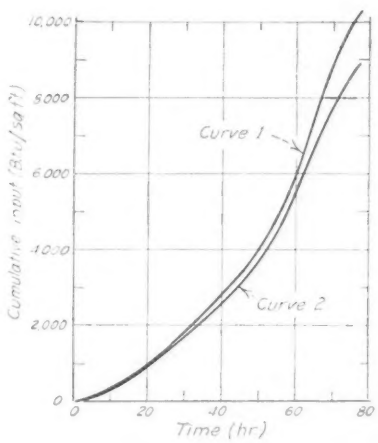

FIG. 5.—Heating curves, 9-in. and 18-in., 2000°F., insulating firebrick. Heating cycle: 24 hr., 80°–600°F.; 24 hr., 600°–1000°F.; 18 hr., 1000°–1800°F.; 6 hr., 1800°–1850°F.; 6-hr. soak at 1850°F.; curve No. 1, 9-in., 2000°F., insulating firebrick, 1.6-lb. straight; curve No. 2, 18-in., 2000°F., insulating firebrick, 1.6-lb. straight.

the rate of input drops off because of successively smaller increases in temperature from hour to hour.

The cumulative curve indicates that the total input to the 11-in. crown is 53,000 B.t.u. per sq. ft. for the total cycle. Separate preliminary studies indicate that 18- and 29-in. firebrick walls on the same cycle have a heat input within 10% of this same amount. For the heavier walls, the effect of the heat flow decreases as the thickness increases, but the lower flow is offset by an increased amount of heat storage.

Figure 5 shows the input required for two walls constructed of insulating firebrick which weigh 27 lb. per cu. ft., corresponding to 1.6 lb. per 9-in. equivalent; the walls are 9 in. and 18 in. thick, respectively. These curves also include the combined effect of heat storage and heat flow although they are not plotted separately. The total input of the 9-in. wall is only 10,300 B.t.u. per sq. ft. or 20% that of 11-in. firebrick. The input for the 18-in. wall is 8950 B.t.u. or 17% that of the 11-in. firebrick. A similar study for a $13^1/_2$-in. wall of insulating firebrick resulted in a curve almost identical with that of the 18-in. wall, indicating that, for this cycle, no thermal efficiency would be gained by an increase in thickness greater than $13^1/_2$ in.

In the development of the input curves, the same cycle was used for both types of brick. The cycle actually could be shortened for the light brick as shown on the curves. The following input data were obtained on the three walls from the 60th to 65th hour:

		Insulating firebrick (B.t.u.)	
(Hr./B.t.u./sq. ft.)	11-in. firebrick (B.t.u.)	9-in.	18-in.
Input at 65	38,000	7250	6550
Input at 60	30,800	5900	5400
Difference	7,200	1350	1150
Hourly rate	1,450	270	230

If the same firing rate were maintained on the lighter walls as on the heavier walls, a more rapid increase in temperature would have resulted, thus reducing the firing time and the total period of heat-flow losses.

The results show that a 9-in. wall and crown of insulating firebrick are acceptable for use in place of the usual massive construction. It should be noted, however, that the weight of the insulating firebrick has a direct bearing on the economies to be obtained because increased weight causes both the heat storage and heat flow to increase and thus adds to the total input.

Curves such as those shown in Fig. 5 may be developed for any type of cycle and wall thickness. With an increase in the length of the cycle, the heat-flow loss becomes greater because it has more time in which to operate. The storage of heat in thick walls also increases in importance because more time is given to approach the equilibrium condition.

These curves, however, do not take into consideration the effect of residual heat left in the walls from a previous firing. Such heat reduces the required heat-storage input somewhat, but it also increases the heat flow because a thermal head has been established between the outside wall and the surrounding air, and the heat flow becomes an active loss from the beginning of the cycle rather than being subjected to a time lag as shown in Fig. 4.

VII. Heat for Drying

A point sometimes raised is that the high heat storage of a firebrick kiln wall is regained for use in drying the ware and therefore is not a loss. Although some heat is regained, it is expensive. In the first place, only a portion of the fuel burned in the kiln is absorbed by the walls and ware. A good share goes up the stack, and some of it is never fully utilized because of inefficient combustion; from 35 to 50% and sometimes more is lost from these causes, depending on the type and length of cycle, the operating temperatures, and the efficiency of combustion. If the most favorable condition of a stack loss of only 35% is considered, this means that of 100 B.t.u. introduced into the furnace to heat the walls only 65 B.t.u. are absorbed; the remainder goes up the stack. Of the 65 B.t.u., a certain amount is lost due to heat flow during the firing period, and the remainder goes into the heat storage of the walls. Figure 4 shows that for the 11-in. crown only 30,200 B.t.u. out of a total of 53,000 B.t.u. (or 57%) are retained in the brick. For 18- and 29-in. walls, the percentages would be approximately 68 and 87%, respectively, for the specific

cycle studied. Thus at the start of the cooling cycle, for each 100 B.t.u. put into the furnace for the walls, the following number would be stored in the walls:

Wall thickness (in.)	Percentage of 65 B.t.u.	B.t.u. stored
11	57	37
18	70	46
29	87	57

Of this total, only a certain portion will go back into the kiln during the cooling cycle for drying purposes because some heat is constantly flowing to the outside. The amount of heat that returns to the kiln depends on the percentage of thermal equilibrium in the wall at the start of this phase of operation and also on the characteristics of the cooling cycle. The longer the cooling period lasts the more opportunity there is for heat to be lost to the outside. An exact determination of the distribution of heat is difficult because it depends on a number of variables; a reasonable assumption, however, would be that only about 50% of the heat is returned to the kiln and the remainder is lost by heat flow to the outside If 37 to 57 B.t.u. are stored in the walls when cooling starts and if only one half is regained, then, of the 100 B.t.u. that were fired into the kiln expressly for the walls, only 19 to 29 B.t.u. are useful for drying.

Instead of using heavy walls solely to obtain heat for drying, it would apparently be more economical to obtain drying heat by efficient direct firing if the heat from the ware itself is not sufficient for this purpose.

VIII. Kiln Design with Insulating Firebrick

Figure 5 shows that walls with 9 to 13½ in. of insulating firebrick will give a high degree of thermal efficiency. Many kilns, some operating at temperatures up to 2750°F., have been so constructed. To obtain the maximum benefit of efficiency and life from such kilns, experience has pointed out certain definite rules to be followed. The more important of these are as follows:

(1) Kiln temperatures should be investigated carefully to insure the use of the correct type of insulating firebrick. If the brick is used beyond its temperature limit, it may be expected to show shrinkage.

(2) Allowance should be made for certain parts of the kiln that are hotter than other parts, such as the walls and crown directly over the burners or grates. In such zones, a higher temperature type of insulating firebrick may be necessary than in the remainder of the kiln.

(3) Firebrick should be used in all locations that are subject to physical punishment, such as the combustion chambers of coal-fired kilns and around doors.

(4) All firebrick should be bonded into the insulating firebrick to insure a solid construction.

(5) Fuel-burning equipment and combustion chambers, bag walls, and flues should be designed on the basis of the reduced fuel input. Some adjustment and modification on a new design may be required after the initial firings are made in order to obtain the maximum improvement in results.

(6) A catwalk should be constructed over the dome to prevent men from walking on the dome while it is hot (e.g., when measuring the subsidence of the ware through the well hole).

(7) Skewbacks may be made of the same material as the crown, inasmuch as they are subjected to no more load than the brick in the crown.

(8) If the kiln is located out of doors, it should be completely weatherproofed. One method of protecting the crown is to lay a course of red brick on top of the insulating firebrick and to slush cement grout over the brick; after several firings, a second slush coating should be applied. Weatherproofing compounds are also satisfactory if they are renewed periodically.

(9) Insulating firebrick should be laid with a good grade of air-setting, high-temperature mortar. The extra cost is compensated for by a tighter structure and longer life of the brick. The use of fire-clay or cement-sand-lime mortars will eventually result in loose joints with the possible necessity of relaying the brick.

Acknowledgment

The writer wishes to express his appreciation to T. W. Garve and John R. Clark for their encouragement and suggestions, and special acknowledgment is due J. W. Moffat, R. Bradley, and J. Selvig of the Babcock & Wilcox Company for the many hours they spent on the calculations required to develop the heating curves presented with this paper.

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RELATION BETWEEN AIR AND WATER PERMEABILITIES OF BUILDING BRICK*

By R. T. Stull and Paul V. Johnson

Abstract

Air and water permeabilities were determined on specimens of five different series of brick. Under continuous flow, the air permeability was constant with time of flow, whereas the water permeability was not, inasmuch as it increased with time of flow for some brick and decreased for others. Whether the permeability increased or decreased depended on the size of the mean effective capillary radius of the brick. The ratio of air-to-water permeability was not, inversely proportional to the viscosities of the two fluids in conformity to Poiseuille's equation although the ratio approaches this proportion as the mean effective capillary size of the brick increases.

I. Introduction

During an investigation on the properties of the pore system in brick and their relation to frost action,[1] the air and water permeabilities were determined on specimens of five different series of brick. The air permeability of the brick was constant with respect to time of flow whereas the water permeability was not. Consecutive determinations under continuous flow of water showed an increase in permeability for some brick; for others, the rate decreased with time. In a total of 45 brick, 16 exhibited an increase in water permeability with time; permeability was nearly constant in 1; and in 28, the permeability decreased with time of flow.

Numerous investigators of fired clay products have reported decreasing water permeability with time, but data indicating an increase in permeabilities have not been recorded.

II. Water Permeability

Water permeabilities determined under constant pressure at intervals of 5 or 10 minutes are shown plotted against time of flow in Figs. 1 to 5, inclusive. Each curve represents the water permeability of an individual brick, which is designated by its letter and number and also by its mean effective capillary radius,[1] r. The reading at zero time was made after sufficient water had

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 1, 1941 (Structural Clay Products Division). Received August 25, 1941.

[1] R. T. Stull and P. V. Johnson, "Properties of Pore System in Brick and Their Relation to Frost Action," *Jour. Research Nat. Bur. Standards*, **25** [6] 711–30 (1940); *Ceram. Abs.*, **20** [4] 94 (1941).

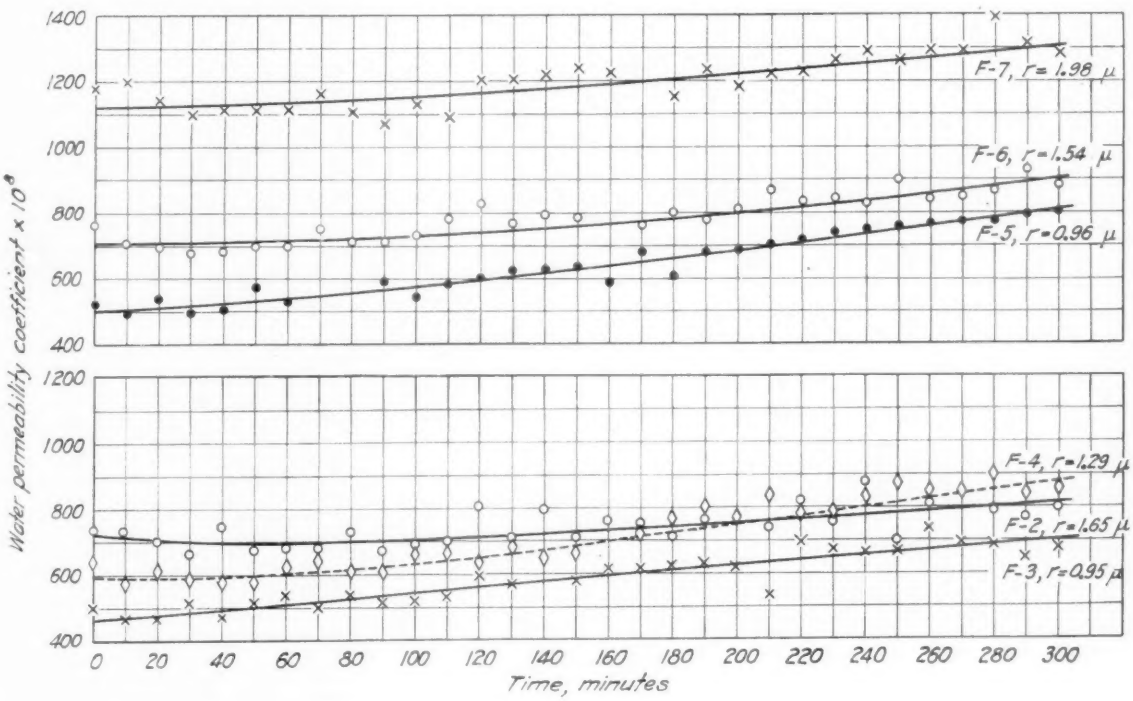

Fig. 1.—Change in water permeability with time of flow for brick of series F (stiff-mud clay).

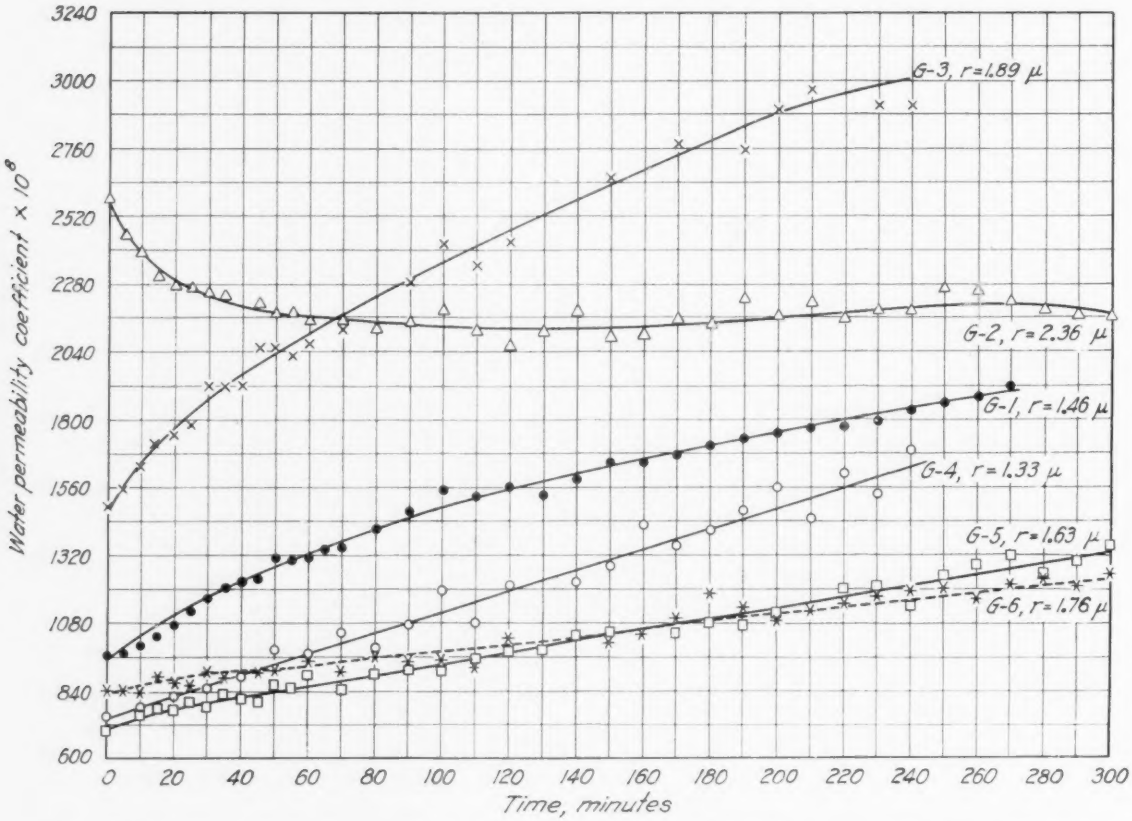

FIG. 2.—**Change in water permeability with time of flow for brick Nos. 1 to 6 of series G (stiff-mud shale).**

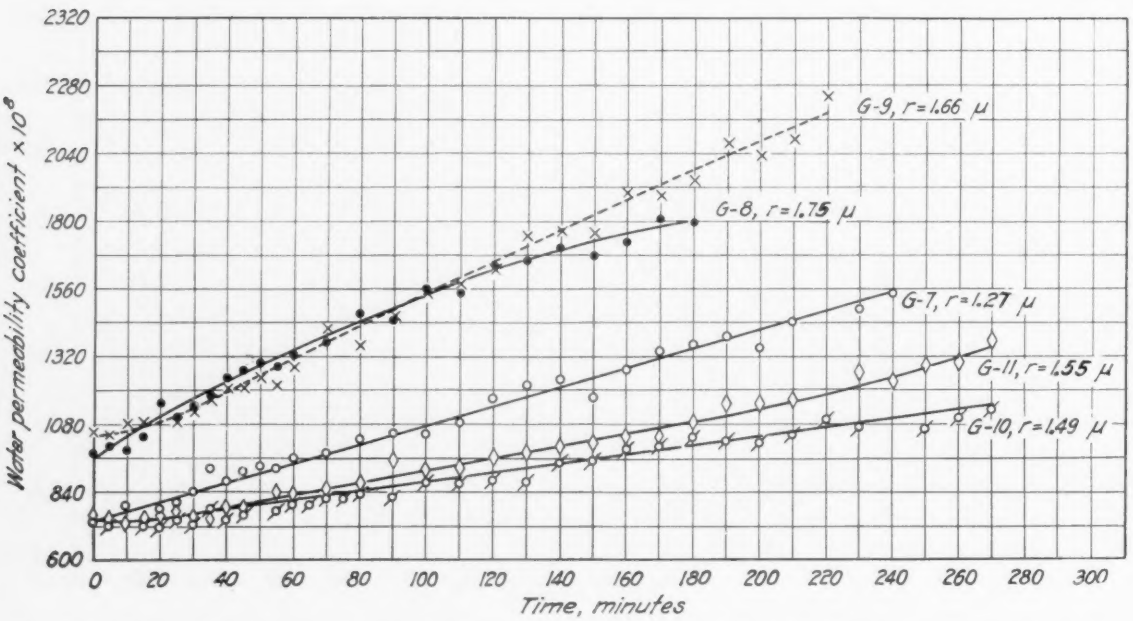

FIG. 3.—**Change in water permeability with time of flow for brick Nos. 7 to 11 of series G (stiff-mud shale).**

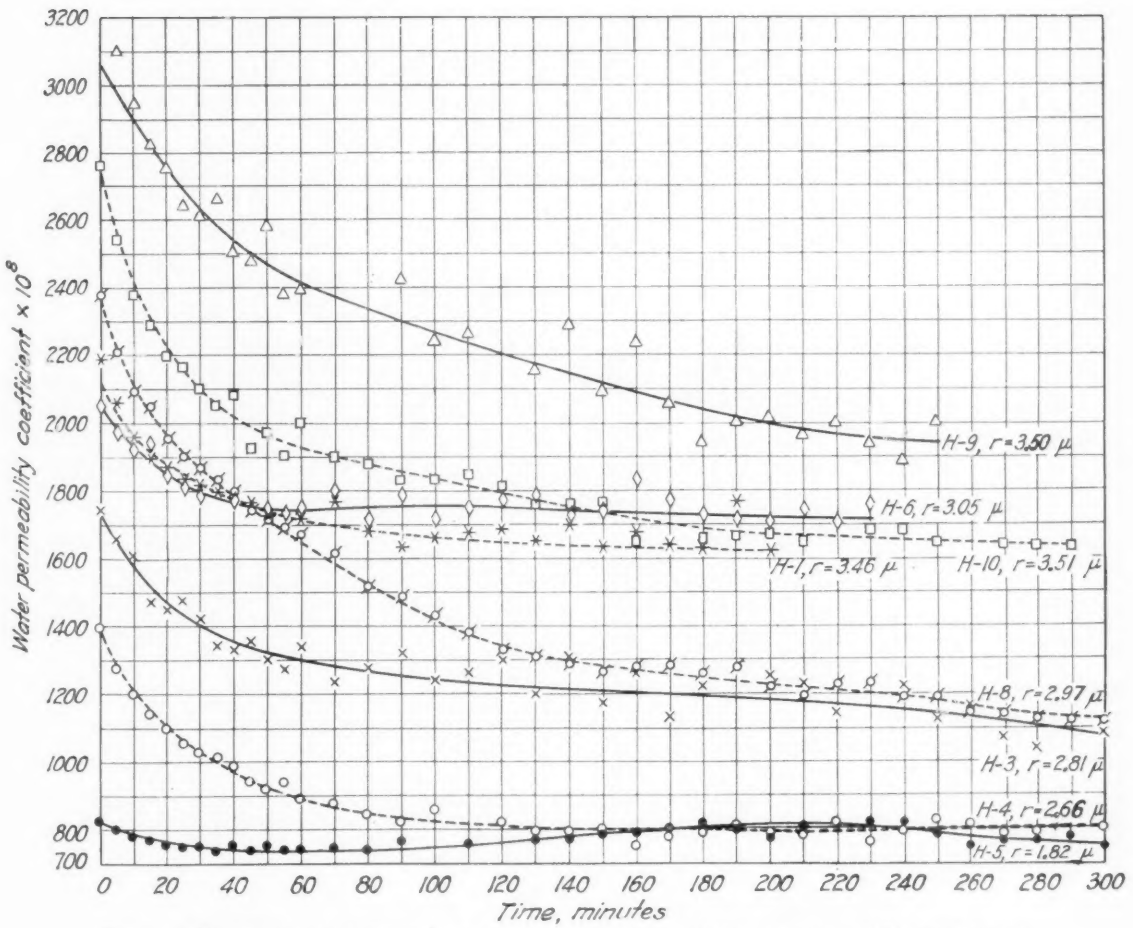

FIG. 4.—Change in water permeability with time of flow for brick of series H (stiff-mud shale).

passed through the brick to cover the upper surface to a depth of about 2 mm.

All members of series F and G, except G 2, exhibited an increase in water permeability; G 2 and each specimen in series H, J, and K showed decreasing water permeability with the possible exception of H 5 whose permeability is substantially constant.

The causes of these changes in water permeability are not definitely known. Bartell[2] attributes a decline in water permeability of porcelain disks to progressive clogging by small particles mechanically broken off and carried into the pores by the water. Muskat[3] also considers that air, dissolved in the water, may become entrapped in the pores upon evolution and thus decrease the permeability.

Progressive solution of the walls of the capillaries with consequent increase in their cross sections would explain the increasing permeability, but the specimens are not of such nature that solution would be probable.

The mean effective capillary radii of those brick in which permeability increased under continuous flow are smaller than those in which water permeability decreased. It would seem, however, that clogging of the pores by particles or by air would be more pronounced in those brick of smaller pores and would therefore cause a decrease rather than an increase in the permeability.

The average size of the capillary radius of the brick appears to effect a separation between increase and decrease in permeability under continuous flow. With the exception of one brick in which the permeability was nearly constant, all brick having mean capillary radii of less than 2 microns exhibited an increase in water permeability with time of flow; conversely, all brick having mean capillary radii greater than 2 microns exhibited decrease in water permeability.

III. Relation Between Air and Water Permeabilities

According to Poiseuille's equation, the ratio of the rate of flow of air to that of water through a porous medium would be inversely proportional to the viscosities of the two fluids; therefore, when n' and n are the respective viscosities of water and air, f is the rate of flow (permeability) of air and f' is the rate of water; then

$$n'/n = f/f' = a \quad \text{or} \quad (f/f')/a = 1.$$

Inasmuch as the water permeability of a brick changes continuously under continuous flow, it has no definite

[2] F. E. Bartell, "Permeability of Porcelain and Copper Ferrocyanide Membranes," *Jour. Phys. Chem.*, **15**, 659–74 (October, 1911); p. 664.

[3] M. Muskat, Flow of Homogeneous Fluids Through Porous Media. McGraw-Hill Book Co., Inc., New York, N. Y., 1937.

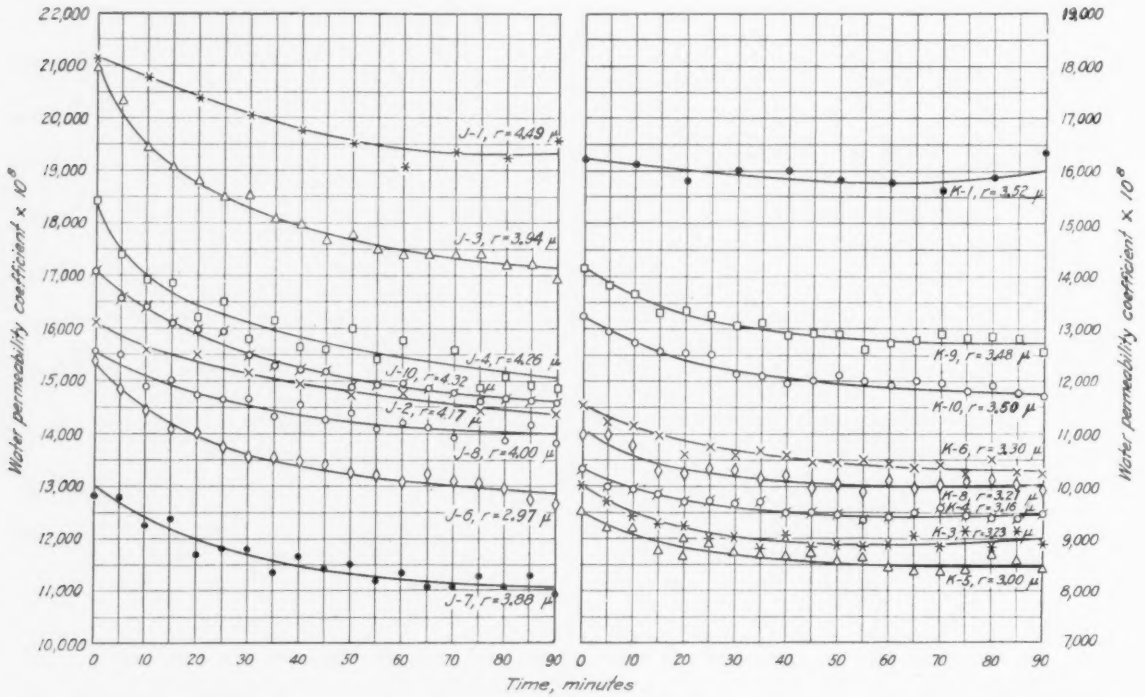

FIG. 5.—Change in water permeability with time of flow for brick of series J and K; *left*, series J (dry-press clay); *right*, series K (dry-press clay).

TABLE I

RELATION BETWEEN RATIO OF AIR TO WATER PERMEABILITY AND CAPILLARY RADIUS FOR FIVE SERIES OF BRICK

Series	Average f/f'	Average $(f/f')/a$	Average $r(\mu)$
F	572	10.3	1.37
G	481	8.7	1.64
H	410	7.4	2.97
K	184	3.3	3.28
J	169	3.0	4.13

$a = 55.5$.

permeability value and, therefore, the ratio of its air-to-water permeability is not a constant. As a means of comparison, however, the f/f' and also the $(f/f')/a$ ($a = 55.5$) values were calculated for the average air permeability and the average initial water permeability for each of the five series of brick. These values, together with the corresponding mean effective capillary-radius values, are given in Table I. The data, though confined to rather narrow limits, indicate that f/f' is decreasing toward 55.5 and $(f/f')/55.5$ toward unity as r is increasing. This suggests that there is some pore size where the ratio of the water permeability to that of air may be inversely proportional to the respective viscosities of the two fluids.

NATIONAL BUREAU OF STANDARDS
WASHINGTON, D. C.

INFRARED AS AN ANALYTICAL TOOL: DEHYDRATION OF SILICIC ACID DERIVED FROM FELDSPARS*

By E. W. Koenig

Abstract

The application of infrared radiation to the evaporation and dehydration of silicic acid solutions derived from feldspars has been studied with the view of replacing the present water-bath evaporation and oven-dehydration procedures. An earlier study was made of the efficacy of single dehydrations of silicic acid from the standpoint of percentage recovery of silica. Comparative data indicate that the proposed procedure is definitely superior in this respect to the one formerly used.

A comparative time-study tabulation is included, which indicates that the proposed method is capable of reducing the analytical time to a material extent. The use of the method for the analyses of other silicates is mentioned briefly, and a hypothesis is advanced to explain the apparent departure from the previously accepted theory of the mechanics of the dehydration of silicic acid.

I. Introduction

The vulnerability to error of the common routine determination of silica in acid-insoluble silicates is greater than that of most any other constituent ordinarily evaluated. Complete recovery is difficult, and the contamination of the silica by compounds co-precipitated during the analytical process can reach a value of considerable consequence. True values for this constituent for this reason are often the result of a fortuitous compensation of errors.

Efforts to eliminate or at least to lessen in quantity the loss in silica occasioned by incomplete recoveries are usually instrumental in increasing the contamination of the silica residue by foreign salts. This in turn requires an aftertreatment of the silica residue to determine the actual extent of the adulteration, all of which make the present procedure extremely long.

The silicate sample, in the ordinary course of analysis, is fused with an excess of an alkali carbonate, the fused mass is dissolved in a mineral acid, and the resultant solution of salts is evaporated to "bone dryness." Solution of the soluble salts in a dilute mineral acid and filtration follow, and the filtrate is again evaporated to dryness. The residue at this point, which contains silica in minor quantities, the R_2O_3 and RO groups as chlorides, and a great excess of alkali chlorides, is baked at a predetermined temperature for such a period as to insure complete dehydration of the silicic acid. This latter condition is difficult to attain, and some silica undoubtedly escapes as a soluble silicate because solubility equilibrium is probably reached before complete dehydration is accomplished. The soluble salts are again dissolved in a mineral acid, and the residue is collected and combined with that originally obtained. The residues are ignited to constant weight in platinum, the weight is recorded, and the true silica is obtained by volatilization of the silicon dioxide as SiF_4 by evaporation with hydrofluoric acid.

(1) Literature Review

Much of the literature covering this dehydration treatment is controversial as to the optimum time-temperature cycle required to achieve the necessary insoluble state of the silica. As early as 1902, Hillebrand[1] recognized this fact, but he made no firm recommendations as to procedure except to warn against extremely high temperatures when magnesia is present because of the likelihood of the formation of acid-soluble magnesium silicate. Lehner and Truog[2] later expanded the earlier work to include the effect of foreign salts on the solubility of silica in a mineral acid. Many of their results were interesting but rather inconclusive because of the difficulty experienced in obtaining constant temperatures in the equipment at their disposal. One point which they expressed deserves mention.[3]

> There is no advantage in dehydrating for more than two hours or in carrying out the dehydration under reduced pressure. This indicates that the failure to recover all the silica in one dehydration is not due to insufficient dehydration but to the great opportunity afforded by the large mass of silica for its direct solution during the acid treatment.

With the exception of Hawley,[4] who states that silica is soluble in hydrochloric acid in quantities directly proportional to the amount of acid used, later investigators have more or less discounted the importance of such losses.

For the actual dehydration, Hillebrand and Lundell[5] recommend 110°C. for one hour and indicate that higher temperatures are not too harmful except when working with titaniferrous or ferruginous material or with

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., March 31, 1941 (General Session on Silicate Analysis). Received October 11, 1941.

[1] W. F. Hillebrand, "Common Errors in Determination of Silica," *Jour. Amer. Chem. Soc.*, **24**, 362–74 (1902).

[2] Victor Lehner and Emil Truog, "Quantitative Determination of Silica," *ibid.*, **38**, 1050–63 (1916).

[3] *Ibid.*, p. 1059.

[4] F. G. Hawley, "Accurate Silica Determination in Commercial Analysis," *Eng. Mining Jour.*, **103**, 541–43 (1917).

[5] W. F. Hillebrand and G. E. F. Lundell, Applied Inorganic Analysis, p. 721. John Wiley & Sons, New York. 929 pp.

materials containing magnesia in an appreciable amount. They present data to show that unrecovered silica after two evaporations can amount to several milligrams and that high baking temperatures tend to contaminate the filtered silica with members of the R_2O_3 group. Groves[6] states that several milligrams of silica escape the initial evaporation, and he sets 130°C. as the maximum allowable temperature, whereas Sutton[7] suggests 2.5 hours at 130°C. as the proper time-temperature cycle for materials containing as much as 20% of alumina. Webster and Lyle[8] used perchloric acid to effect dehydration of silica in glasses, and recoveries are of a high order by their procedure. Some difficulty, however, has been experienced with its use when working with feldspars or other silicates which have a high alumina content due to the formation of insoluble aluminum perchlorates (this has also been mentioned by Hillebrand and Lundell[9]).

(2) Previous Laboratory Tests

A study was made in 1934 in these laboratories of the efficacy of single dehydrations of silicic acid derived from feldspars. This investigation was conducted primarily to determine whether a definite ratio exists between recovered and unrecovered silica, and, if this proved to be the case, whether this ratio has the necessary degree of precision to be analytically useful. The initial decomposition in this work followed the conventional pattern, and determinations were made of the individual silica recoveries and of their accompanying nonvolatile residues. In all of the trials, the time-temperature cycle for the second dehydration treatment was controlled closely for one hour at 110°C. Some eighty successive determinations were made covering feldspars of widely varying chemical composition. Table I indicates the results obtained on a representative portion of this series.

These data show that (1) the silica which has escaped the initial recovery is essentially a constant of small numerical value regardless of the amount of silica originally present, (2) the nonvolatile residue obtained from the first silica recovery closely approximates in value that obtained for the second silica recovery, and (3) the greater portion of the nonvolatile residue is introduced by efforts made to complete the recovery of the silica by dehydrating a second time.

It could therefore be assumed under normal conditions of procedure, that, the weight of the first silica residue plus the weight of its accompanying nonvolatile residue could be considered the true silica value without any great chance of error. The nonvolatile residue could then be recovered by conventional means and added to the original silica filtrate before the determination of alumina and the alkaline earths. The latter procedure would prove applicable, however, only in those cases where a volumetric procedure for the determination of alumina was chosen because of the effect of the presence of the unrecovered silica on gravimetric determinations of this constituent. Although the revised method had definite advantages over the more involved double-dehydration procedure, there was always the question in the mind of the analyst as to whether some nonanticipated abnormality of procedure might produce a low silica recovery without a like increase in the nonvolatile residue. This method was abandoned after a short period of use.

(3) Use of Inverted Hot-Plate Evaporators

The use of inverted hot-plate evaporators is not a new idea. Several applications have been described in the literature and a few have made special mention of their usefulness in silicate analyses. The experience in this laboratory with this type of equipment has been none too good when it was applied to the evaporation and dehydration of silicic acid solutions because the severe treatment invariably produced high nonvolatile

[6] A. V. Groves, Silicate Analysis, p. 49. Thomas Murby and Sons, London. 230 pp.

[7] André Sutton, "Exact Determination of Silica in Sands and Aluminous Silicates," *Ing. Chim.*, **19**, 32–43, 57–63 (1935).

[8] P. A. Webster and A. K. Lyle, "Short Methods for Chemical Analysis of Glass," *Jour. Amer. Ceram. Soc.*, **23** [8] 235–41 (1940).

[9] W. F. Hillebrand and G. E. F. Lundell, *loc. cit.*, p. 723.

TABLE I

Sample No.	1st SiO_2 (mg.)	1st nonvolatile residue (mg.)	Total SiO_2 (mg.)	2nd SiO_2 (mg.)	2nd nonvolatile residue (mg.)	Total SiO_2 (mg.)
70*	665.8	0.8	666.6	0.8	1.4	666.6
70	665.4	1.0	666.4	1.4	1.4	666.8
70	665.2	1.2	666.4	1.6	1.6	666.8
70	666.0	0.8	666.8	1.0	1.2	667.0
70	665.4	1.0	666.4	1.4	1.4	666.8
99†	685.4	0.8	686.2	1.0	1.6	686.4
99	685.6	1.0	686.6	1.0	1.4	686.6
99	685.8	0.8	686.6	1.0	1.0	686.8
99	685.6	1.0	686.6	1.2	1.4	686.8
B919	697.4	1.0	698.4	1.4	1.2	698.8
B922	640.0	0.8	640.8	1.0	1.2	641.0
M4470	682.0	1.2	683.2	1.0	1.2	683.0
M4472	662.0	0.8	662.8	1.0	1.4	663.0
M4473	657.0	0.6	657.6	0.8	1.2	657.8
M4474	662.0	1.0	663.0	1.0	1.2	663.0
M4490	729.2	1.2	730.4	1.2	1.2	730.4

National Bureau of Standards recommended values: *666.6; †686.6.

residues. No data are available, unfortunately, to show the ratio between recovered and unrecovered silica.

With the introduction of the infrared lamp as a means of heat transfer in the automotive finishing industry, interest was aroused in the possibilities of the use of this mode of heat transfer for other purposes; among these were the drying of photographic films and plates and of printed matter, the baking of "soda crackers," and others. Promising results were obtained practically in every case, and the time of drying or of baking was materially reduced in most applications. The experiments were conducted in this laboratory with the same considerations in mind.

II. Procedure

The procedure used in the current work is relatively simple: a 0.5-gm. portion of the prepared feldspar sample is intimately mixed with 0.7 gm. of anhydrous Na_2CO_3 by grinding in an agate mortar. The admixture is quantitatively transferred to a regular form 75-ml. platinum dish, covered, and heated at the highest temperature of a blast burner until a "glass-clear" fusion is obtained; this requires not more than three minutes (continued heating is disadvantageous because a more complex, less soluble, glass is formed on heating after the solution of the sample in the flux has been obtained). The fused mass is brought into solution with a minimum of dilute HCl; this amount must be determined by trial (no hard and fast rules can be laid down for this treatment), and the solution of the sample should require not more than ten minutes.

The platinum dish containing the sample solution is placed on the water bath and allowed to digest for about 10 minutes to evolve dissolved gases, and the infrared bulb is swung into position over the dish.

A GE R40 110-volt 260-watt internally coated bulb was used in the latter stages of this investigation with good results; this bulb replaced the diathermy bulb with the Alzak aluminum reflector which was originally used. The distance between the bottom of the lamp and the top of the dish should be approximately $1^1/_2$ in.

Evaporation of the solution proceeds rapidly without further attention. When the residue is dry, the dish is moved to the surface of the water bath, and the heating under the lamp is continued until no more NH_4Cl fumes are evolved when a stirring rod wetted with NH_4OH is passed over the dish. The dehydration can be completed over water, but the process is relatively slow. Dehydration with the dish resting on a nonconducting surface, such as asbestos or transite, is conducive to the production of high nonvolatile residues.

The residue is cooled and is drenched with HCl, and the analysis is completed in the usual manner; the filtrate is reserved for the further separations customary to silicate analyses.

As mentioned before, the main objective in this study was to determine whether a saving in analytical time could be accomplished by the use of this equipment. That this objective was reached is shown in Table II. The operations preliminary to the actual evaporation and dehydration in either case were identical.

TABLE II

PRESENT PROCEDURE

Double dehydration with intervening filtration

	Hr.
1st evaporation	2.66
2nd "	2.50
Dehydration	1.00
Total	6.16

PROPOSED PROCEDURE

Single evaporation and dehydration with infrared bulb

	Hr.
Evaporation	0.90
Dehydration	0.50
Total	1.40

Rate of evaporation of silicic acid solutions

Vol. (ml.)	Bath alone (hr.)	Bath and lamp (hr.)
25	2.25	0.75
35	2.66	0.90
50	3.25	1.25

The most surprising results obtained in this study were found not in the anticipated saving of analytical time but in the fact that complete recovery of silica is apparently accomplished by one evaporation and dehydration under the infrared bulb. A section of the tabular data illustrating this point is shown in Table III.

TABLE III

Sample	Uncorrected silica (mg.)	Nonvolatile residue (mg.)	True silica (mg.)	Deviation (mg.)
70*	667.4	1.0	666.4	−0.2
70	667.4	1.0	666.4	− .2
70	667.6	1.2	666.4	− .2
70	667.2	0.4	666.8	+ .2
70	668.0	1.2	666.8	+ .2
99†	687.8	1.2	686.6	.0
99	688.0	1.2	686.8	+ .2
99	687.8	1.2	686.8	.0

National Bureau of Standards recommended value: *666.6; †686.6.

It will be noted that the initial weight of silica plus its nonvolatile residue in practically every case is well in excess of the true silica value (compare with Table I), a condition not found in the use of the earlier method, and that the nonvolatile residues are not excessive. As further confirmation of the absence of silica in the filtrate, methods were used which involved the colorimetric determination of silica. A negative reaction was obtained in every case.

III. Discussion of Results

The author has no definite explanation for the difference in results obtained by the use of the two methods for the dehydration of silicic acid derived from feldspars. A hypothesis has been advanced, based on the opacity of quartz to all radiations above 7000 Å and on the relative transmission and absorption of certain portions of the spectrum by water. No analytical data are available to prove this theory, but all evidence points to the fact that the main advantage of the present equipment over the inverted hot-plate heater lies in the fact that the emission spectrum of the present

equipment is confined to the 5500 to 16,000 'A' portion of the spectrum, whereas with the older type of heater, the greater portion of the heat transmission is in the region above 20,000 'A'. If it is assumed that silicic acid in its various forms behaves in a manner similar to quartz, that is, opaque to all radiations above 7000 'A', either method might prove equally efficacious insofar as the dehydration of silicic acid is concerned. If the further assumption is made that the salts and solutions of salts surrounding the individual particles of silica show the same transmission and absorption as does water, the answer to the lower nonvolatile-residue values obtained by the proposed procedure is realized, the preponderance of plus 20,000 'A' radiation being instrumental to produce the high nonvolatile residues mentioned before when the ordinary inverted hot plate is used. This might be analogous to the effect of "overbaking" in the orthodox procedure.

As further evidence of the fact that none, or practically none, of the nonvolatile residue is produced under this evaporation and dehydration treatment, several trials were conducted in which the sample was fused with an excessive amount of the alkali flux and the flocculant silica so formed was filtered off after the solution of the fused mass in hydrochloric acid and before evaporation and dehydration took place. The residues were ignited, and the nonvolatile residues were recovered; in every case, values were found for this contaminant which closely approximated those found after evaporation and dehydration of the solution as in the described procedure. When the filtrates from this separation of the flocculant silica were evaporated and the remaining silica was dehydrated and the residues were ignited, values of from 0.1 to 0.2 mg. of nonvolatile residue were found.

IV. Use of Method for Analysis of Materials Other Than Feldspar

The use of the method in the analyses of other ceramic raw materials and products has been attempted. Silicates, which are free (or practically free) of magnesia, react in a manner similar to feldspar; these include glass sands, potters' flints, nepheline syenite, aplite, china clays, and others Glasses, limestone, and other magnesia-bearing silicates show the same low recoveries by the proposed method as are obtained by single evaporations by the orthodox procedure.

V Other Applications

The equipment has proved almost indispensable for the drying and charring of filter papers before ignition. This is particularly true in the case of silica residues when used in conjunction with a hot plate; the paper chars quickly leaving a white residue for the final ignition. Loss of the finer silica particles by drafts caused by ignition of the paper is thereby avoided. The charring of organic residues, such as cupferron precipitates, proceeds without the usual spattering and danger of loss if the lamp is used before the final ignition. The equipment may also be used in drying large quantities of sands, feldspars, clays, and micas.

VI. Summary

The use of infrared as a means of heat transfer for the evaporation and dehydration of silicic acid solutions derived from feldspars offers certain advantages over the procedure commonly used for this purpose. Complete recoveries apparently are accomplished without the necessity of a second dehydration treatment, and the time required for the analysis is materially reduced without sacrificing analytical accuracy. Equipment cost is nominal.

The use of the method for the determination of silica in materials other than feldspar is mentioned briefly, and the use of this mode of heat transfer for certain other applications is suggested.

Acknowledgments

The author wishes to express his appreciation to Harry W. McIntyre for much of the analytical data covering the earlier work on the single dehydration of silica and to Thomas C. Carson, Jr., for aid in the current study.

Consolidated Feldspar Corporation
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RESEARCH PROBLEMS IN AN ARCHEOLOGICAL CERAMIC LABORATORY*

By Frederick R. Matson

Abstract

Pottery fragments found in archeological excavations may be used (1) to study ceramic shapes and decorations, (2) to date other discovered materials, and (3) to survey cultural changes. A technical analysis of the bodies and glazes will also yield information of use in reconstructing the past. The work that has been done in this field is discussed. There are many other problems that ceramists with archeological interests might investigate.

I. Introduction

The ceramic fragments found by an archeologist are usually one of the most informative groups of materials he can use in trying to reconstruct the civilizations of the past. At almost every place where man established a home, he manufactured pottery. The vessels themselves were often fragile and easily broken, but the resulting fragments, potsherds, were "potentially immortal." From a study of these fragments, it is possible to reconstruct the original shapes and to become familiar with the decorative elements used in the painted, stamped, or incised designs.

Sherds occur through all of the occupational debris in sufficient quantities to correlate the changes they show in pottery styles with the architectural remains, stone, and metalwork that are found at the same level in the excavation, and they may be used to date these materials relatively when inscriptions or coins are not discovered. After such associations have been established, they may also be used to determine which levels in nearby sites were contemporaneous.

It is usually safe to assume that most of the pottery found at a site was made there or nearby, although a few sherds might represent containers of trade items received from other regions. When a conqueror subdued a town or when a group abandoned a site because of drought, crop failure, or plague, the ceramic record would be left.

The contents of cemeteries may also be useful. Even though the family of the deceased might be too poor to bury jewelry or other treasures with him, bowls containing food would at least be left for his use on the dark voyage of faith. In the richer graves were placed many of the finer pieces of pottery that are now in our museums documenting the history of ceramics.

II. Design and Decoration Interpretations

The plastic nature of clay makes it an especially sensitive medium of expression, one in which foreign influences, changes in style, and the development of new uses for ceramic products are quickly and often unconsciously reflected. The role of the individual artist is of far less importance in effecting changes in shape and decoration than has often been suggested because cultural tradition repels or stifles the nonconformist.

Innovations in ceramic products are often important clues that may lead to a better understanding of the life of the people who made them. To maintain a balanced viewpoint, however, the interpretation of these changes must be weighted by what knowledge is available about other aspects of the civilization. The appearance of pottery shapes that are clearly imitations of metal vessels, for example, may be taken as evidence that there were some copper or bronze containers in use even though none were found in the excavations, because the tendency to make cheap imitations of expensive objects is not a recent development. Impressed or painted decorations on bowls and jars may furnish a clue to the type of basketry and textile weaves in use. The animals and plants familiar to the potters or the artistic relationships between the people and those of other regions can be observed in the designs. There is a vast field of study in ceramic decoration from which data are obtained that add to the knowledge concerning the people who made the pottery, their place of origin, and their interrelationships through commerce and, perhaps, through war with other men.

III. Ceramic Data Interpretations

There are questions, however, which arise in the study of whole vessels and sherds, that an analysis of shape and decoration cannot answer. Was all of the pottery made locally at the site or are some sherds, which have a different "feel," the remnants of imported vessels? Are all of the red, buff, gray, and black sherds found in an excavation made of the same materials? What is the significance of the color differences? Is a slip present on certain pieces? To what temperature was the pottery fired? Were pieces made by hand or on the wheel?

Archeologists realize that a knowledge of the properties, the place of origin, and the degree of purification of the clays used, the manner in which the vessels were made and fired, the nature of the pigments and glazes employed in the decoration together with their provenance and technique of application, and the effects of weathering are factors that must be considered if the ancient pottery is to yield all of the historical information of which it is capable.

In some archeological publications there are now recorded such items as color, hardness, texture, purity of the clay, and a glossary of the technical terms used. There has been little consistency in the color termi-

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 2, 1941 (Art Division). Received July 3, 1941.

nology, and the description of the other items is on a subjective basis. Such terms as "hard-fired" and "poorly baked" have been used incorrectly by authors when they had no knowledge of the thermal behavior of the clays used, thus providing further sources of quotable misinformation.

An important advance toward standardization of the objective description of pottery by the field archeologist was made in the publication of "Standards of Pottery Description" by March.[1] Among other things, he suggests standards for the recording of color, hardness, surface reflectance, and types of crazing that are sufficiently accurate for archeological purposes and yet do not require elaborate equipment or specialized training in order to use them.

Quantitative chemical analyses of body compositions have limited usefulness because the proportions and purity of the materials vary to a considerable degree.[2] Petrographic studies of thin sections have given more information because they reveal the minerals that were present in the clay and thus help to determine the region from which the clay came and the degree to which it had been purified or tempered.

The index of refraction of glazes indicates consistency of compositions, but spectrographic analyses and microchemical tests should also be made.

It is hardly necessary to point out that a large amount of material should first be examined with a binocular microscope for preliminary sorting into textural and mineralogical types. Adequate samples of each group may then be selected for thin sectioning. Raw clays, obtained at or near the site where the pottery was found, also furnish important information.

Many of the papers published on technical and archeological pottery problems have been important contributions to the history of ceramics. Other reports, unfortunately, have not been useful because of at least one of the following reasons: (1) The technical report on the specimens examined does not contain sufficient archeological data to enable the reader to identify the test pieces accurately with respect to their provenance. This information is essential if the material is to be used for comparative purposes. (2) Information is seldom published about the manner of sampling or the degree of consistency in the materials from which the test pieces were selected. Average results are often reported with no statement as to the number of pieces analyzed or the range in determined values. As primitive ceramics were made from materials that were not always of the same degree of purity and as the manner in which the amounts were proportioned could hardly be called accurate, it is important to consider the representativeness of the results before basing conclusions on them. (3) The report prepared by the chemist or ceramic technologist is abstracted or incorporated in the paper dealing with the pottery in such a way that the limiting conditions under which the technological conclusions are valid are not clear and may lead the reader to false assumptions. The way in which such tests were made is often omitted. (4) The technical report may be appended to the archeological manuscript or published separately with no attempt to interpret the data from a cultural viewpoint. Unless the information is helpful in understanding the pottery in relation to other aspects of the life of a people there may not be much point in having the work done. (5) The criticism that insufficient use is made of comparative material should possibly be added to this list, although this is hardly fair because at the present time little useful comparative material is available.[2]

IV. Reports of Technical Researches

Considerable technological ceramic research has been done during the past six years with materials from many parts of the world. By far the best publication that has appeared, one that might almost be termed the bible of this field, is that by Shepard.[3] After presenting a thorough discussion of the methods of technological analysis applicable to archeological materials and suggesting a group of descriptive pottery standards for the field worker, Shepard reports on her study of modern pueblo pottery making and presents in detail the results of her microscopic, chemical, and physical analyses of the pottery from Pecos, New Mexico. She was able to demonstrate that many of the ceramic types that the excavators of Pecos had thought were of local manufacture were actually imported from other areas which she identified. The relative amounts of local and imported pottery used at Pecos during different periods in its history are indicative of the economic position of the town and of its trade connections with other communities. Without the technological analysis of the pottery, not only would the ceramic history of the site have been incorrect (for none of the sherds were recognized megascopically as having been imported), but the general archeological conclusions regarding the position of Pecos in the Southwest would have been incomplete.

Other technological studies of North and Central American ceramics have dealt with the identification and provenance of the tempering materials, the determination of firing temperatures, methods of construction, and descriptive standards and terminology. It is interesting to note that the American Indian potter often added coarse tempering material to the clay even when it was unnecessary from the standpoint of shrinkage control or plastic strength. In parts of the southeastern United States, apparently white materials were preferred for use as aplastic. The force of cultural tradition in the inheritance of processes of manufacture

[1] Benjamin March, "Standards of Pottery Description, with an Introductory Essay by Carl E. Guthe," *Occasional Contributions from Museum of Anthropology of Univ. of Michigan*, No. 3, Ann Arbor, 1934. 55 pp.

[2] A summary of much of the technical literature on ancient ceramics, particularly the chemical analyses, can be found in J. R. Partington, Origins and Development of Applied Chemistry, Longmans, Green, and Co., London, 1935; 597 pp. This book must be used with caution because, although it is a compendium of a tremendous amount of material and as such is most useful, it does not contain a critical evaluation of the references given.

[3] Anna O. Shepard, "Technology of Pecos Pottery," part 2 of A. V. Kidder and A. O. Shepard, "The Pottery of Pecos, II," *Papers of Southwestern Expedition, Dept. of Archaeology, Phillips Academy, Andover, Mass.*, **2** [7] 389–587 (1936).

and in the selection of materials is apparent in such pottery. Evidently the Indian women did not question the methods of the past or try to improve them; they even used these methods after they had moved to other regions where the raw materials were somewhat different. This is illustrated by a site in central Michigan. The sherds there contain large amounts of rock fragments that are 2 mm. or more in diameter, which were derived from weathered granitic schists. Because the clays near the site were very sandy, they did not require the addition of tempering material. The potters were probably aware of this for they made pipes from the same clay without the addition of aplastic.

There is much work yet to be done in studying the distribution, types, size, and amounts of tempering material in American Indian pottery and in the correlation of these data with the clays used, the firing temperatures, and the kind of culture in which each ware occurred.

Alfred Lucas of the staff of the Cairo Museum has done outstanding work in identifying the materials used in the arts and crafts of Egypt and in reconstructing the techniques employed,[4] but he has not published much information concerning the cultural implications of his analyses.

There is some technological work being done with sherds from many regions, but there would be no point in attempting to summarize these studies here. One other book might be mentioned, that of Hetherington,[5] who has made an intensive study of the Chinese glazes and has explained in simple terms the role of copper, iron, and other materials in the production of the beautiful Chinese porcelains. After more studies of this type have been made and further archeological ceramic data are available, it will be possible to treat in greater detail the history of ceramics in its cultural and historical setting.

V. Research Centers

At the present time, there are only three laboratories in the United States where considerable research is being done on the technical study of ancient pottery. Miss Shepard is working at Boulder, Colorado, under the auspices of the Carnegie Institution of Washington and is making detailed studies of certain southwestern United States and Central American pottery. At the University Museum, University of Pennsylvania, Vladimir J. Fewkes is working on problems dealing with methods of construction and terminology and with neolithic pottery of southeastern Europe. At the Museum of Anthropology of the University of Michigan, the emphasis is placed on petrographic and physical studies of pottery from the eastern United States, Mesopotamia, and Syria.

VI. Conclusions

It is apparent that the best results can be obtained in archeological ceramic research only when the archeologist and the ceramist work closely together. This is an interesting field open to those who wish to combine technical ceramic training with that in archeology.

The aims of such studies have been well summarized by Shepard[6] who says,

> The immediate purposes of a ceramic technological investigation are to identify materials and locate their sources, to study the indications of workmanship, and to describe properties by reference to exact, impersonal standards. There are two ultimate aims in the interpretation of technological data. The first is to trace the history of the potter's craft, the second is to recover more accurately and in greater detail than is possible by other methods the evidence which pottery preserves of cultural development, contacts, and influences.

Archeological research can be greatly aided through such work, but only when it is remembered that a variable is always present, namely, the human element. Each type of ware was made by several potters who differed one from the other in skill, carefulness, family needs, and temperament.

Museum of Anthropology
University of Michigan
Ann Arbor, Michigan

[4] Alfred Lucas, Ancient Egyptian Materials and Industries, 2nd ed., revised. Ed. Arnold & Co., London, 1934.

[5] A. L. Hetherington, Chinese Ceramic Glazes, 2nd ed. Cambridge, England, 1937. 76 pp.

[6] A. V. Kidder and A. O. Shepard, *loc. cit.*, p. 389.

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CERAMIC HISTORY

ALEXANDER SILVERMAN

Alexander Silverman was born on a rainy wash-day, Monday, May 2, 1881, to a dry-goods merchant, Philip Silverman, and his wife, Hannah Schamberg, who was constantly in the business with him. The father's father, Henry, was also a merchant. These two account for Alex's businesslike habits. The mother's father, Alexander Schamberg, was an accomplished violinist, and his mother's sister Nettie played and taught both violin and piano. So we account for Alex's musical interest.

The mother's other sister, Regina, was a teacher of German, which she taught to Alex and his two sisters; she, also, was instrumental in their learning French as children. Hence Alex's command of languages.

It was Aunt Regina who took Alex to William Jacob Holland, chancellor of the old Western University of Pennsylvania (now University of Pittsburgh) in the spring of 1897 to see if he could enter in the fall, though he had spent only one year in Central High School in Pittsburgh. Through special tutoring that summer, he gained admission, enrolling under Francis Clifford Phillips, an international authority on the chemistry of petroleum and natural gas.

Professor Phillips, whom Alex assisted in his senior year, had at times served as a consultant to some of the glass manufacturers in Pittsburgh. When Alex was graduated in 1902 with second honors in science, his professor sent him to the Macbeth-Evans Glass Company in Charleroi; only six other chemists were employed in the American glass industry at that time, so Alex was a "pioneer."

The first problem presented to Alex was the reproduction of alabaster glass; the process of its manufacture had been lost about 1880, although the glass had been made since around 1600. Opal glasses transmitted an orange or fiery light which made illumination with Edison carbon-filament lamps (before the day of the tungsten lamp) too yellow. George A. Macbeth had unearthed some old alabaster glass and had found that it was free from opalescence. He immediately realized its usefulness. As Alex states, "The analysis showed considerable alumina, so I used the hydrated oxide. The glass was horrible. It looked like curdled milk. Knowing that salt vaporized at high temperatures, I added it to the batch and, Eureka! alabaster was reborn. As far as I know, I was the first to introduce alumina as such into a glass batch. Perhaps I was also the first to use salt."

Later, Alex learned that salts dissolved in water, ionized, and precipitated colloids. By analogy, he advanced the theory of dissolved electrolytes acting similarly in glass and accounted for the influence of salt in alabaster melts. Alex also dug up analyses of old LeBlanc soda ash and of pearl ash and found chlorides and sulfates in all of these.

About 1880, the Semet-Solvay or ammonia-soda process for soda-ash manufacture replaced the old LeBlanc method, and the purification of pearl ash improved. Without the contaminating chlorides and sulfates, opal glasses resulted and the art of making alabaster glass was lost. Alex rediscovered it and, in addition, made improvements and effected economies in silvering, for the Macbeth-Evans Glass Company made enormous quantities of hollow reflectors. At the end of about a year and a half, Alex, who had already received one raise, felt he might have another. When he asked Mr. Macbeth, he was dismissed. It has been said that the Company was "in the red" at the time when alabaster manufacture was revived by Alex, but that in the eight years which followed his dismissal they cleared a million dollars.

Having lost his position with nothing in view but less remunerative steelworks jobs, Alex wanted to desert chemistry for music, for he held a diploma as "teacher of violin," but his father dissuaded him by saying, "Perhaps you do not know enough chemistry. Go and study some more." Following this advice, Alex went to Cornell University for a year. In the fall of 1905, he was appointed instructor in chemistry at the University of Pittsburgh, where he has been teaching ever since.

In 1908, Alex was called into his first consulting service by the Gill Brothers Company of Steubenville, Ohio, which he served for many years. (It was also in 1908 that Alex and Elrose Reizenstein were married.) Alex's work at this Company led to the perfection of a brilliant type of selenium ruby glass for signal lenses. Later, in another consulting capacity, he developed a selenium amber for lead glasses which was the first on the American market and perhaps the first lead selenium amber ever produced. He has produced numerous new effects for his various clients and has served them constantly toward the perfection of their products and the development of unusual glasses to meet special specifications. His forte is the field of opal and alabaster glass, although his collection of small specimens of various glasses produced from time to time would, if properly assembled, yield practically a complete spectrum of color.

Honors and Awards

In 1930, the University of Pittsburgh conferred on Alexander Silverman the honorary degree of Doctor of Science.

It was also in 1930 that Professor Silverman completed twenty-five years of service at the University of Pittsburgh. On that occasion, several hundred faculty members, alumni, and friends, among them leaders in the fields of chemistry and ceramics, attended the alumni anniversary dinner held in his honor. At this time, a portrait of Professor Silverman, painted by Ellis M. Silvette, was presented to the University. The portrait presentation address was made by the late William Jacob Holland, then director of the Carnegie Museum (and the chancellor of the University of Pittsburgh when Alexander Silverman was a student there).

In 1936, the honorary degree of Doctor of Science was conferred on Professor Silverman by Alfred University.

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April 21, 1941	1794	247	47	563	220	2871
May 21, 1941	1839	249	47	580	220	2935
June 21, 1941	1875	249	45	584	220	2973
July 21, 1941	1898	251	46	587	220	3002
August 21, 1941	1935	253	45	590	220	3043
September 21, 1941	1963	254	43	592	220	3072
October 21, 1941	1980	254	43	613	220	3110
November 21, 1941	2013	256	39	610	220	3138
A Year Ago	1950	259	26	567	220	3022

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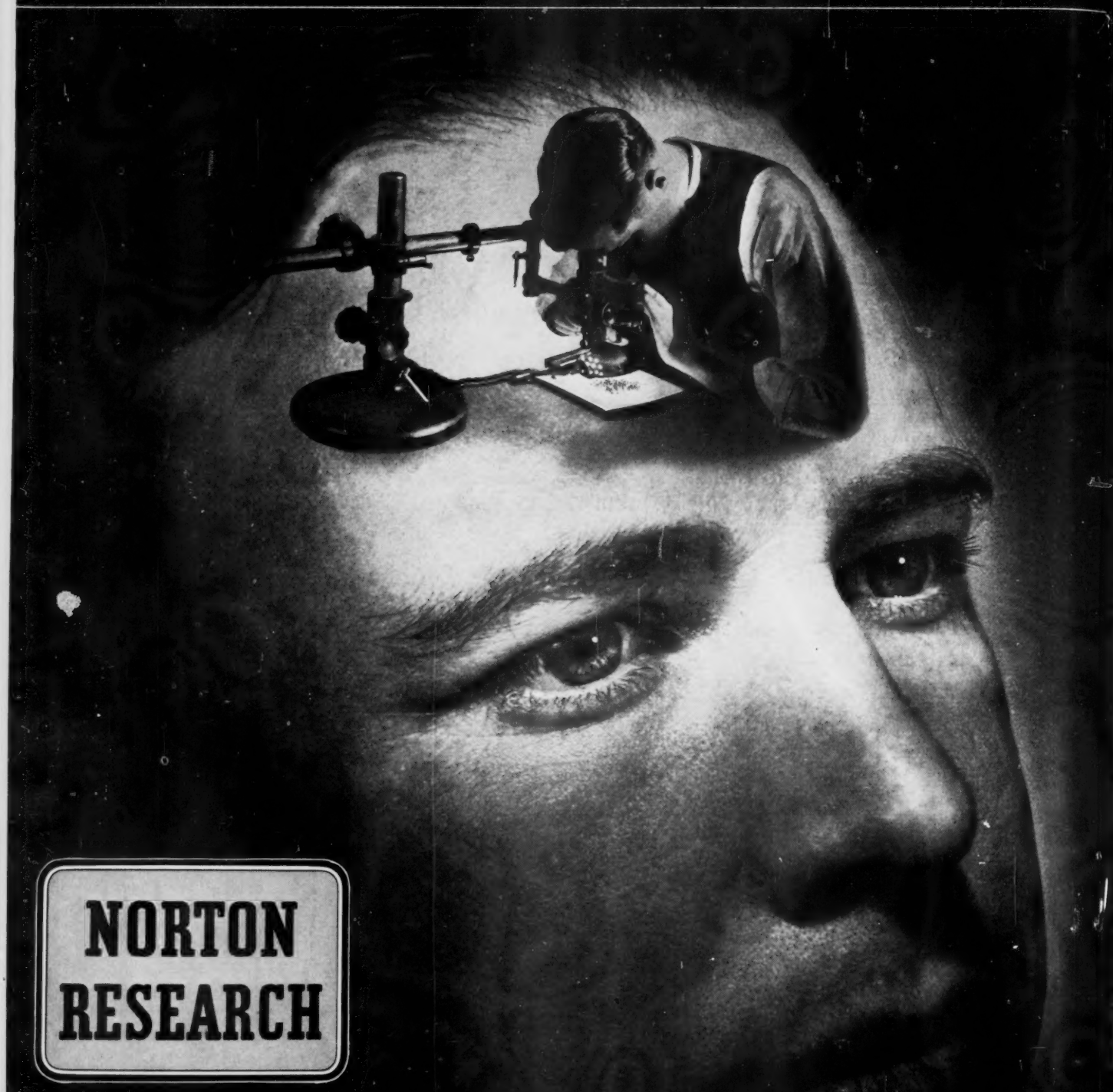

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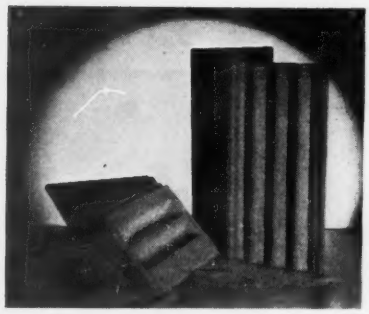


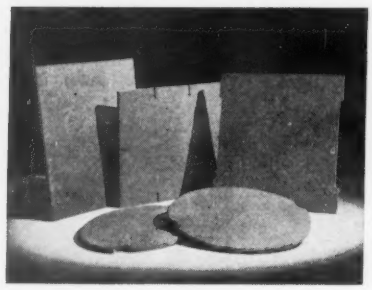
Wavy Muffle Plates Mean Dropping Cost Curves

The corrugated design of ALUNDUM muffle plates for tunnel kilns means

— greatly increased radiating surface.

— very thin cross-section, without loss of strength or stability.

Thinness and increased radiation add up to greater kiln efficiency — more B. T. U.'s passed through to the products being fired.



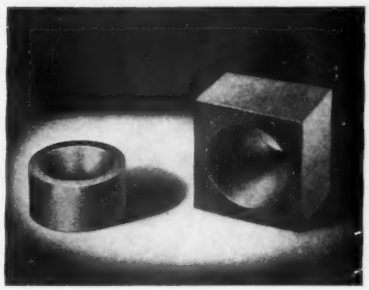
CRYSTOLON Batts up Kiln Capacity 60 – 500%

By substituting open setting with strong, thin CRYSTOLON batts, for kiln settings, increases in kiln capacity have frequently been measured as

— up to 500%, *an average of 200%,* in electrical porcelain firing.

— often 60% in firing of chinaware.

The reason for this increase is the extraordinary strength of CRYSTOLON batts, permitting very thin cross section.



Where Thermal and Chemical Punishment Is Worst — Long-lived ALUNDUM Burner Blocks

Most indifferent to chemical conditions of all super-refractory materials, fused alumina is ideally suited for use in burner blocks. There, under continuous flames of terrific heat, ALUNDUM material keeps on the job without softening, spalling, deformation, long after blocks of other materials would have to be discarded.

To meet widely-differing customer needs, in shape, depth and design of burner block openings — Norton engineers' many years varied experience are at your service.

Used for 4 Years — Muffle O.K. for New Furnace

Tough on our sales department — but ALUNDUM muffles stand up so long that when a customer recently built a new enameling furnace, he found the ALUNDUM muffle of a dismantled furnace was good enough to be transferred. Four years' constant use hadn't spalled, softened or cracked the muffle tiles.

Such service means much in low, long-term refractory costs—and even more in prevention of interruptions, down-time and spoiled products.

Refractory Shapes and Cements of CRYSTOLON (silicon carbide), ALUNDUM (fused alumina), and fused Magnesia Grains

NORTON COMPANY, WORCESTER, MASS.

A MERRY CHRISTMAS

and

A PROSPEROUS NEW YEAR

American Ceramic Society

2525 N. HIGH STREET COLUMBUS, OHIO

On March 20, 1941, the Pittsburgh Section of the American Chemical Society presented to him the Pittsburgh Award for distinguished achievements.

Publications

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Patents

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"Illuminator for Optical Instruments," U. S. 1,444,400, Feb. 6, 1923.

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International Meetings and Foreign Lectures

Professor Silverman is recognized internationally as an authority on the chemistry of glass. He has lectured or presented papers in Belgium, France, Spain, Italy, and Germany. He has also represented the United States at the following international meetings:

1930, Liége, Belgium. U. S. delegate and delegate of The American Ceramic Society to the International Meeting of Industrial Chemistry; also delegate of the National Research Council and National Academy of Sciences to the X Conference of the International Union of Chemistry.

1934, Madrid, Spain. U. S. delegate and delegate of The American Ceramic Society to the IX International Congress of Chemistry; also councillor from the National Research Council and National Academy of Sciences to the XI Conference of the International Union of Chemistry.

1936, Lucerne, Switzerland. U. S. delegate of the National Academy of Sciences and National Research Council to the XII Conference of the International Union of Chemistry.

1938, Rome, Italy. U. S. delegate and delegate of The American Ceramic Society to the X International Congress of Chemistry; also councillor from the National Research Council and National Academy of Sciences to the XIII Conference of the International Union of Chemistry.

Membership in Scientific Societies, Clubs, and Fraternities

American Chemical Society, American Ceramic Society: Fellow; vice-president, 1931; Trustee, 1932; representative on Division of Chemistry and Chemical Technology, National Research Council, since 1939; Chairman, Committee on Honorary Membership since 1938; Chairman, Committee on Education, 1940; Electrochemical Society, American Association for Advancement of Science (Fellow), American Institute of Chemists (Fellow), American Association of University Professors, American Institute of Chemical Engineers, Pennsylvania Academy of Science, Society of Glass Technology (England) (Fellow), Society for Protection of Science and Learning (England), Institute of Ceramic Engineers, Association Scientifique et Technique de Ceramique (France), Pennsylvania Chemical Society, Chemists' Club of New York City, Authors' Club of Pittsburgh, Sigma Xi, Phi Lambda Upsilon, Omicron Delta Kappa, and Pi Lambda Phi (Honorary Member).

ACTIVITIES OF THE SOCIETY

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R. E. Birch	4	C. L. Parsons	1
R. B. Carothers	1	Ralston Russell, Jr.	1
Donald Hagar	1	L. R. Whitaker	1
R. G. O'Meara	1	Office	4

Student

R. E. Birch	1	M. E. Holmes	1
A. F. Greaves-Walker	1	R. M. King	1
E. C. Henry	4	R. L. Stone	1
N. W. Taylor	2		

Grand Total 26

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Corporation

JOHN DOUGLAS Co., John F. Douglas (voter), Cincinnati, Ohio.

Personal

ALLEN, HORACE E., 2248 Parkwood Ave., Toledo, Ohio; sales representative, Ohio Hydrate & Supply Co., Woodville, Ohio.

*BARRETT, HARVEY N., JR., 845 Hanna Bldg., Cleveland, Ohio; service engineer, Basic Refractories, Inc.

*HELLMERS, HENRY T., 401 Walnut St., Alexandria, Ind.

KANTNER, OGDEN A., 562 Cleardale Ave., Trenton, N. J.; sales engineer, United Clay Mines Corp.

LUCKE, HENRY J., 12 East 41st St., New York, N. Y.; patent lawyer.

MOHR, WILLIAM C., 121 Second Ave., Derry, Pa.; research engineer, Westinghouse Electric & Mfg. Co.

MOORE, CARL E., John Douglas Co., Cincinnati, Ohio.

PUNTNEY, L. E., 4609 Cleveland Ave., St. Louis, Mo.; Research Dept., Laclede-Christy Clay Products Co.

REMY, MARC E. DEB., 365 Redfern Ave., Westmount, Quebec, Canada; research chemist and vice-president, Industrial Glass Works, Ltd.

SCHAKE, JOHN A., Marsh Rd., East Rochester, N. Y.; F. E. Reed Glass Co.

SPIKES, W. F., Dept. 817, Sears, Roebuck and Co., 925 S. Homan, Chicago, Ill.; senior chemist (membership formerly in name of R. L. Van Name).

STUCKEY, DAVID L., Box 1052, Macon, Ga.; ceramic engineer, Bibb Clay Products, Inc.

TRUESDELL, GLENN C., 509 12th Ave., Tuscaloosa, Ala.; junior chemical engineer, U. S. Bureau of Mines.

WILLIAMS, HARRY M., 977 Lawrance Rd., Trenton, N. J.; ceramist, Trenton Potteries Co.

Student

University of Alabama: EDWIN R. TODD.
University of Illinois: HAROLD C. JOHNSON.
New York State College of Ceramics: MURRAY A. SCHWARTZ.

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ROSTER CHANGES DURING NOVEMBER*

ANWYL, R. H., Elgin Standard Brick Mfg. Co., Elgin, Tex. (Sugar Land, Tex.)
BESLEY, JOHN S., 719 William St., Joliet, Ill. (Ashland, Wis.)
BREEMAN, LEONARD, JR., Box 425, Bedford, Va. (Brookneal, Va.)
DUSZA, JOSEPH T., Harbison-Walker Refractories Co., East Chicago, Ind. (Rolla, Mo.)
FUNNELL, JOHN, 23 East 1st St., Corning, N. Y. (Munhall, Pa.)
GRACE, HOLT B., Dept. of Ceramic Engineering, Georgia School of Technology, Atlanta, Ga. (Clarkesville, Ga.)
GUNZENHAUSER, ADOLF, 621 West 189th St., New York, N. Y. (Long Beach, N. Y.)
HALL, JAMES L., 1916 Euclid Ave., Chicago Heights, Ill. (Mahwah, N. J.)
HUMMEL, FLOYD A., Grandview Way, Mapleview, Charleroi, Pa. (Syracuse, N. Y.)
HUMMEL, ROY, B. G. Corp., 136 West 52d St., New York, N. Y. (Fostoria, Ohio)
IRWIN, PHILIP P., 109 W. Main St., Carrollton, Ohio (East Liverpool, Ohio)
MULLER, MAX M., 623 Avenue G, Boulder City, Nev. (Cleveland, Ohio)
MUSGRAVE, MORRIS C., U. S. Gypsum Co., Oakfield, N. Y. (Alfred, N. Y.)
PACKMAN, WILLARD D., Garfield Refractories Co., Box 96, Bolivar, Pa. (New Florence, Pa.)
SCHIFFERLI, LEO M., JR., 48 Linwood Ave., Buffalo, N. Y. (Rochester, N. Y.)
SCHWARTZ, FREDERICK W., R.F.D. 1, Box 870, Homestead, Pa. (Pittsburgh, Pa.)
TEAGUE, JO M., JR., 150 Barksdale Dr., Atlanta, Ga. (Clarion, Pa.)
WHIPPLE, A. D., 5241 N. Kimball Ave., Chicago, Ill. (Alexandria, Ind.)
WILSON, ASHLEY F., 90 Alabama St., Buffalo, N. Y. (Newark, N. J.)

* Address in parentheses is former address.

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EARL E. HITE, 410 S. Third St., Toronto, Ohio.
RICHARD P. KELTING, 624 Islington St., Toledo, Ohio.
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JOHN H. KOLSTAD, 5614 Merkle Ave., Parma, Ohio.
WILLIAM J. KNAPP, N. Y. State College of Ceramics, Alfred, N. Y.
ROBERT J. MCCANN, National Enameling & Stamping Co., Granite City, Ill.
MAX M. MULLER, 623 Avenue G, Boulder City, Nev.
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CHARLES V. MYERS, 428 N. Light St., Springfield, Ohio.
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ALFRED J. POST, 1714 Fallowfield Ave., Pittsburgh (16), Pa.
EDWARD H. ROLLFS, 105 Elm St., Gardner, Mass.
WILLIAM A. SCHOLES, Company C, Aviation Cadet Det., Chanute Field, Ill.
EVERETT W. SHARP, 415 Woodlawn Ave., Mexico, Mo.
WILLIAM D. SPORE, 346 West 4th St., East Liverpool, Ohio.
JAMES K. STEVENSON JR., 48 Burncoat St., Worcester, Mass.
EVERETT A. THOMAS, 1655 South Ave., Niagara Falls, N. Y.

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JACK F. DAY, 1126 Maple Ave., Zanesville Ohio.

JOHN OGDEN IN AMERICAN FIELD SERVICE

John T. Ogden, editor and publisher of *Glass Industry*, 11 West 42d St., New York, N Y., writes as follows to Ross C. Purdy, General Secretary of The Society.

November 6, 1941

Dear Ross:

As you may have heard some months ago I felt the urge to lend a hand in the "big effort" and volunteered for service in Africa with the American Field Service.

Now that my departure is imminent, I find that time is all too short to do so many things I'd like to do—among them to drop around and see my old friends. But that just can't be done, so I'm taking this means of saying "au revoir" for about a year.

In the meantime, the fellows who have worked with me will carry on and I'll be looking forward to seeing you when I get back.

With best regards,

JOHN T. OGDEN

J. A. PASK RECEIVES PH.D. DEGREE

Joseph A. Pask received the degree of Doctor of Philosophy in Ceramic Engineering at the University of Illinois in October, 1941. His thesis subject was "A Study of the Migration of Ions in Glass."

Mr. Pask received the B.S. degree in Ceramic Engineering at the University of Illinois in 1934 and the M.S. degree at the University of Washington in Seattle in 1935. During the past three years, he has been an instructor in the Department of Ceramic Engineering at the University of Illinois; at present, he is acting assistant professor of ceramic engineering at the University of Washington.

CHICAGO SECTION

A meeting of the Chicago Section was held on October 3, 1941, at the Electric Club, Chicago, Ill. Principal speakers were Oliver C. Ralston, chief engineer, Nonmetals Div., U. S. Bureau of Mines, College Park, Md., and Thomas C. Poulter, scientific director, Armour Research Foundation, Chicago, Ill.

Dr. Ralston gave an interesting talk on substitute ceramic materials and told how the mineral deposits of the United States are being exploited for use as substitute materials for imported materials.

Pictures of Admiral Richard E. Byrd's second Antarctic expedition were shown by Dr. Poulter, who was senior scientist and second in command of the expedition.

—CHARLES R. FILIPPI, *Secretary-Treasurer*

PITTSBURGH SECTION

The Pittsburgh Section has elected the following officers for 1942:

Chairman: GEORGE J. BAIR, Mellon Inst., Pittsburgh, Pa.

Vice-Chairman: E. E. MARBAKER, Mellon Inst., Pittsburgh, Pa.

Treasurer: LOUIS A. SMITH, Jones & Laughlin Steel Corp., Aliquippa, Pa.

Secretary: RAYMOND M. SHREMP, Lava Crucible Co., Zelienople, Pa.

A meeting of the Section will be held on Tuesday, January 13, 1942. C. B. Mershon, Manufacturers' Light & Heat Co., Pittsburgh, Pa., will talk on gas burning and control equipment.

—LOUIS A. SMITH, *Secretary*

RUTGERS UNIVERSITY

Fall Meetings

The Rutgers Ceramic Club and Student Branch of The American Ceramic Society held their first meeting of the new college year on October 13, 1941. Approximately one hundred and thirty persons attended.

J. D. Tetrick, E. I. du Pont de Nemours & Co., Inc., R. & H. Chemicals Dept., Perth Amboy, N. J., spoke on "Vitreous Enameling of Sheet Steel." He discussed the fundamentals involved, described the process and various operations employed in the enameling of sheet steel, and emphasized the important changes which have occurred within recent years. A discussion followed the lecture.

At a meeting on November 10, Alexis Pincus, research scientist at the American Optical Co., Southbridge, Mass., gave a talk on the recent discoveries concerning the formation of glass (a detailed account of his talk is given in the opposite column).

The Ceramic Club meetings at Rutgers University have gained wide popularity in view of the excellent attendance and interest shown by the students, alumni of the Department of Ceramics, and others interested in ceramics. A fine program of lectures and speakers has been arranged for the coming year.

Officers

The officers for 1941–1942 are as follows: *President*, William H. Bauer; *Vice-President*, Roy W. Brown; *Secretary*, Harold P. Johnston; *Treasurer*, Richard Winchell; and *Councillors*, George H. Brown and Laurence E. Kane.

Department Enrollment

With the opening of college in September, the enrollment of the Department of Ceramics at Rutgers University totaled seventy-five undergraduate students. This is the largest in the history of the Department. The increase is most gratifying in view of the fact that twenty-five years ago there were only about half a dozen students registered in the course. There are thirty-one freshmen in the Department this year, including two girls from the New Jersey College for Women who are taking the technical course in ceramics. There are also three regular graduate assistants and two special students pursuing graduate work in the Department.

New Staff Member

William S. Emley has joined the teaching staff this year. Professor Emley was formerly technical director of the New Castle Refractories Co., New Castle, Pa. Aside from having a wide experience in the industry, he has taught ceramics at New Castle for several years under the School of Mineral Industries Extension Division of the Pennsylvania State College and has also conducted engineering defense training classes in connection with the national defense program of the U. S. Office of Education.

RESEARCH ON GLASS STRUCTURE

Alexis Pincus, a research scientist with the American Optical Co., Southbridge, Mass., revealed some interesting information concerning the structure of glass at a meeting of the Ceramic Club and Student Branch at Rutgers Univ., New Brunswick, N. J., on November 10, 1941.

Dr. Pincus stated that "the glass we see through is largely composed of the same oxygen we breathe to keep alive." This new insight into the formation of glass, revealed by X rays, demonstrates that glass by volume is mainly oxygen which is kept from disappearing as a gas by a minute volume of silicon.

Recent researches on the atomic structure of glass prove for the first time that 92% of the volume is occupied by oxygen ions, 5% by sodium ions, 2% by calcium ions, and only 1% by silicon ions. Oxygen also contributes 95% of the light-bending property of glass.

The small bulk of silicon is the power that prevents the oxygen from escaping into the atmosphere; as a result, glass is formed when the oxides of calcium, sodium, and silicon are fused together.

Dr. Pincus also stated that other elements, such as boron, phosphorus, antimony, tantalum, tungsten, germanium, and columbium, have the same power as silicon to imprison oxygen and make it form glass. Glasses based on some of these elements have been developed and, for special purposes, their optical, electrical, chemical, and other properties are superior to ordinary glasses made with silicon.

UNIVERSITY OF WASHINGTON

News of Seniors

Ben Davies and James F. McKinnell, Jr., will receive their Bachelor of Science degrees in Ceramic Engineering in January, 1942. Their theses titles, respectively, are "Effect of Acid-Soluble Constituents in Talc on Properties of Ceramic Mixes" and "Making of Pottery and Glazes from Pacific Northwest Clays." Mr. McKinnell is at present stationed in Hawaii as an ensign in the U. S. Navy.

Jack Pittman dropped out of school this year. He is now employed by the Northwest Glass Co., Seattle, Wash.

Allen J. Erickson and Carlton E. Goudge will receive degrees in June, 1942. Their theses titles, respectively, are "Application of Glazes to Structural Clay Products" and "Use of Quartz as an Antiplastic in Fire-Clay Refractories."

NEW YORK STATE COLLEGE OF CERAMICS

The Student Branch at the New York State College of Ceramics held a meeting on November 25. R. M. King, Dept. of Ceramic Engineering, Ohio State Univ., Columbus, Ohio, discussed recent developments in the enameling industry.

Keramos initiated five new members at its meeting on November 2. Following the initiation, brief talks were given by Malcolm Beals, Ralph Rhodes, and Don Wheaton concerning their summer work in ceramic plants. This discussion provided such an interesting program that similar talks will be given in the future by other members.

The Saint Pat's Board, made up of seventeen senior ceramic engineering students, is being assembled, and plans will soon be formulated for the Festival which is scheduled to take place on a week-end as close as possible to March 17, 1942.

The ceramic art students at the New York State College of Ceramics held a Christmas sale of pottery on December 9. Teapots, bowls, animals, and candleholders, fired at low temperature and decorated in slip and underglaze colors, were sold. Porcelain and hard-fired Bristol glazes and celadon ware were also on display.

NECROLOGY

WILLIAM A. NOYES

William Albert Noyes, professor of chemistry and director emeritus of the Chemical Laboratory of the University of Illinois, Urbana, Ill., died on October 24. He was eighty-four years old.

W. H. LOCKE ANDERSON

W. H. Locke Anderson, vice-president and general manager of the Edwin M. Knowles China Co., Newell, W. Va., died on November 15 from injuries received in an accident at the factory. He was forty-seven years old.

Mr. Anderson, whose skull was fractured, died without regaining consciousness. His head is believed to have struck the fly wheel on an air compressor. He was not found until some time after he was hurt.

Mr. Anderson was born in East Liverpool, Ohio. He was graduated from the local high school in 1911 and continued his education at Mercersburg Academy, Mercersburg, Pa., and at Cornell University, Ithaca, N. Y., where he received a degree in civil engineering.

Following his graduation, he became associated with the Gary Tube Co., Gary, Ind. At the outbreak of the World War, he entered the first officers' training school at Ft. Benjamin Harrison, Ind., where he was commissioned as a second lieutenant.

He was sent to France with the intelligence department and served overseas for nearly two years. He was discharged after the war with the rank of captain.

Mr. Anderson then went to Youngstown, Ohio, where he became an engineer with the Youngstown Sheet and Tube Company. In 1923, he accepted a position as cost engineer with the Pope-Gosser China Co., Coshocton, Ohio. In 1925, he joined the Canonsburg Pottery Co., Canonsburg, Pa., as plant superintendent.

In 1929, Mr. Anderson became assistant to the president of the W. S. George Pottery Co., East Palestine, Ohio. He first became associated with the Edwin M. Knowles China Company as factory manager in November, 1935.

Mr. Anderson was president and a director of the East Liverpool Rotary Club and was a member of the board of trustees of the Ohio Ceramic Industries Association. He was vice-president of the United States Potters Association in 1937 and president in 1938.

He had been a member of The American Ceramic Society since 1939 and was associated with the White Wares Division.

Mr. Anderson is survived by his widow and two children.

W. H. Locke Anderson

METTA L. SEYMOUR

To the members of this Society prior to 1918, Miss Seymour was known as secretary to Edward Orton, Jr. For nineteen years, she had thus served The Society. She kept the books, mailed out due bills, kept the literature store, and filled orders. Miss Seymour passed away Sunday night, November 22, 1941, after weeks of illness.

Metta L. Seymour

From 1899 to 1918 she served as secretary to Edward Orton, Jr., in his capacity as director of the Department of Ceramic Engineering at Ohio State University, while he was Dean of the College of Engineering, and while he was Director of the Ohio Geological Survey. She

was also bookkeeper for the Standard Pyrometric Cone Company.

When Edward Orton, Jr., obtained leave from the University to enter the Plattsburg Officer's Training School and later to serve in the United States Army, the office management for the Standard Pyrometric Cone Company was entrusted to Miss Seymour, and thus she served until General Orton was mustered out of active army service.

In 1910, her office was moved from Lord Hall on the campus of Ohio State University to the cone factory on North High Street and later to the Orton Memorial Laboratory on Summit Street. Here she served as bookkeeper and private secretary to Edward Orton, Jr., until his passing in February, 1932, and for several months later until the Edward Orton, Jr., Ceramic Foundation took over the property and also the business of the Standard Pyrometric Cone Company. Miss Seymour was then retired on a pension after thirty-three years of service.

CERAMIC NOTES

ILLINOIS CLAY MANUFACTURERS' ASSOCIATION

The autumn meeting of the Illinois Clay Manufacturers' Association was held on November 6 and 7, 1941. Plant visits were made to the following companies: Hill Brick Co., East St. Louis, Ill.; Blackmer & Post Pipe Co., St. Louis, Mo.; Maryland Heights plant of the Alton Brick Co. in St. Louis and the main plant at Alton, Ill.; and Richards Brick Co., Edwardsville, Ill.

A dinner and evening meeting was held at the Coronada Hotel, St. Louis, on November 6.

CERAMIC ASSOCIATION OF NEW JERSEY

The Ceramic Association of New Jersey held a successful autumn meeting on October 18 at the Ceramics Building, Rutgers Univ., New Brunswick, N. J. George H. Brown, director of the Department of Ceramics, was in charge of arrangements for the day. As the meeting was of a social nature, the ladies were cordially invited to attend. About eighty-five members and guests were present.

The program for the morning session included a lecture on "Handicraft and Mass Production" by Eva Zeisel, instructor of ceramic design, Dept. of Industrial Design, Pratt Institute, Brooklyn, N. Y. Mrs. Zeisel has served as a consultant to several potteries in the United States in the matter of design of pottery products to be manufactured by mass production. The development of a good design for mass production is a long and complex process, whereas handicraft design is for the most part accidental. A design to be used for mass production involves the careful consideration of appearance, price, and purpose of the ware to be produced. Her lecture was supplemented with slides and a display of ceramic tableware of unusual design.

A buffet luncheon was served at noon to the members and guests in the laboratories of the Ceramics Building. Following luncheon, the group attended the Rutgers-Fort Monmouth football game. An informal reception and tea was held in the Ceramics Building after the game.

George C. Betz, Star Porcelain Co., Trenton, N. J., president of the Association, presided at the meeting.

Annual Meeting

The annual meeting of the Ceramic Association of New Jersey will be held on Friday, December 19, 1941, at the Ceramics Building, Rutgers Univ., New Brunswick, N. J. Plans for this meeting are well under way, and a fine program of papers and discussions is being arranged.

OHIO CERAMIC INDUSTRIES ASSOCIATION

The annual meeting of the Ohio Ceramic Industries Association was held at Ohio State University, Columbus, Ohio, on October 24 and 25, 1941.

The following officers and members were elected to serve on the Board of Trustees during 1941–1942:

President: CECIL E. BALES, Ironton Fire Brick Co., Ironton, Ohio.
Vice-President: HARRY D. CALLAHAN, U. S. Quarry Tile Co., East Sparta, Ohio.
Treasurer: E. E. HILLYER, Clay City Pipe Co., Uhrichsville, Ohio.
Secretary: HARRY E. NOLD, Lord Hall, Ohio State Univ., Columbus, Ohio.
J. LEO CHILD, Hancock Brick & Tile Co., Findlay, Ohio.
F. H. JOHNSON, Summitville Face Brick Co., Summitville, Ohio.
C. FORREST TEFFT, The Claycraft Co., Box 866, Columbus, Ohio.
ROBERT K. BECK, Metropolitan Paving Brick Co., Canton, Ohio.
G. R. ROBINSON, Hocking Valley Brick Co., Logan, Ohio.
W. KEITH MCAFEE, Universal Sanitary Mfg. Co., New Castle, Pa.
ROBERT E. BOYCE, Harker Pottery Co., East Liverpool, Ohio.
B. T. BONNOT, The Bonnot Co., Canton, Ohio.
F. R. HENRY, Simonds Worden White Co., Dayton, Ohio.

A dinnerware and glassware exhibit was held on the campus from October 20 to October 25 in conjunction with the annual meeting of the Ohio Ceramic Industries Association. The exhibit, sponsored by the Association and the Department of Ceramic Engineering at Ohio State University, was well attended; 616 persons visited the displays throughout the week.

The glassware displays and some of the dinnerware displays have been left for a permanent exhibit in Lord Hall on the University campus.

CENTRAL DISTRICT ENAMELERS' CLUB

The Central District Enamelers' Club held a dinner meeting on December 5, 1941, at the Allerton Hotel, Cleveland, Ohio.

Following dinner, a discussion on the effect of the defense program on the porcelain enamel industry was led by William Brett, Enamel Products Co., Cleveland, Ohio, and C. L. Clawson, Ferro Enamel Corp., Cleveland, Ohio.

Officers for 1942 were elected at this meeting and will be announced in the January, 1942, *Bulletin*.

AMERICAN SOCIETY FOR TESTING MATERIALS

Spring Meeting

The spring meeting and group meetings of committees of the American Society for Testing Materials will be held in Cleveland, Ohio, during the week beginning March 2, 1942. Committee meetings will be in progress from Monday through Friday; the spring meeting technical sessions will be held on Wednesday, March 4.

Forty-Fifth Annual Meeting

The Forty-Fifth Annual Meeting of the American Society for Testing Materials will be held at Chalfonte-Haddon Hall, Atlantic City, N. J., from June 22 through June 26, 1942. —C. L. WARWICK, *Secretary-Treasurer*

Forty-Fourth Annual Meeting
Cincinnati, Ohio
April 19–25, 1942

NOTES AND NEWS

LETTER FROM A. R. OLPIN

Columbus, Ohio,
November 25, 1941

Dear Dr. Purdy:

I should like to request that you encourage members of your Society to submit to Hubert D. Bennett, Hay-Adams House, Washington, D. C., samples of their ware which might suggest to manufacturers how ceramic raw materials could be substituted for some other materials which are not at present readily available. It may well be that the preferential priorities resulting from defense activities could prove beneficial to the ceramic industry.

Mr. Bennett's idea is that there may be many things heretofore made of metals or plastics which could now be made of glass, ceramic materials, or lumber without sacrificing any of the physical properties or other desirable qualities. He called me from Washington and requested that I do what I could to have him provided with articles of manufacture which would suggest how this substitution of raw materials could be used to advantage.

Any assistance which you give in this worthy cause will, I am sure, be greatly appreciated by all concerned with the extension of the use of ceramics.

Very sincerely yours,
A. R. OLPIN, *Research Director,*
Ohio State University Research Foundation

UNIONISM, AN ISSUE IN ENGINEERING

Whether or not to join a labor union has been a moot question among engineers for a long time. That engineers as a group and as individuals will be confronted with this problem seems inevitable.

Considerable thought has already been given to the subject by The American Society of Mechanical Engineers and the American Society of Chemical Engineers. The latter society recently formulated and published a policy on unionism. A statement of a policy formulated by the American Chemical Society is given elsewhere on this page.

Possibly others have made definite recommendations as to whether labor unions have a place in the engineering profession. Clement J. Freund, dean of the College of Engineering, University of Detroit, has made an extensive study of the subject and his article on "Should Engineers Be Unionized" squarely faces the problem.

His article, excerpts of which are given below, is a fair and impartial discussion of a timely subject. It is heartily recommended for careful examination.

"I do not know, of course, what kind of answer the leaders of the profession might formulate, what kind of policy they may some day adopt. But if a young man should come to me and say 'The pressure is on me. Should I join an engineering union?' I think I should counter by asking, 'Do you or do you not aspire to professional standing in engineering?' He will demand to know 'Just what do you mean by professional standing?'

"By professional standing I mean the standing of a comparatively small number of creators and leaders, intellectuals, researchers, organizers, and administrators of industries and other engineering projects who face lay officials and the public, fully conscious that they, and they alone, must answer for what they do. They are universally recognized as professionals. Dr. Wickenden calls them the 'inner professional nucleus'. . . . .

"A common earmark of all professions is the markedly individual character of the professional man and his work. When he performs a professional task he performs it himself. He may have assistants, hundreds of them, but the full responsibility rests upon him alone. . . . .

"On the other hand, solidarity is a common earmark of labor unions. The individual union member is lost in the mass. He expects to accomplish nothing for himself or by himself. The union agent runs his business for him, and the agent represents not him, particularly, but the whole union to which he belongs. . . . .

"Again, the chief aims of professions and of unions are as far apart as the poles. The principal purpose of professions is to advance the public well-being and especially, if need be, the public well-being in preference to the well-being of the individual member of the profession. The principal purpose of labor unions is to fight for adequate or constantly more and more compensation for the members, depending upon conditions. . . . .

"'If you desperately need a larger income, if you and your wife cannot possibly exist on the salary which you can independently obtain, and if you have abundant evidence that the union can actually obtain for you the greater income you must have, then join the union.

"'But let me warn you that the price which you must pay for these immediate advantages is almost certain exclusion from professional status later. You cannot be a union man now and a professional man later; you must now choose one or the other. I appreciate that it may be a terribly difficult choice, but you must choose.

"'Likewise join the union if you have no desire whatever to become professional, if you lack the confidence to strike out for yourself, if you feel most secure in a group of your fellows, if, perhaps, you are secretly afraid that you will always belong to the multitude.

"'If, on the other hand, you and your family can somehow struggle along through the lean and early years, if you can stretch and stretch again to make ends meet, if you are eager to become professional, if you know you can excel, and if you are making progress, then you should certainly stay out of the union.'

"But the young engineer may continue, 'It's easy for you to talk that way, but you don't know what I'm up against. I am making progress, my wife and I can make ends meet, and I want very much to become a professional engineer. But our drafting room is practically a closed shop. I don't care about the union, but I can't stay in the place unless I sign up.'

"I can think of only one answer. That one answer is, 'Quit your job and find another just as soon as you possibly can. Oh yes, I know that that is a harsh thing for me to say and probably a hard thing for you to do, for many reasons, but I say it because I am most firmly convinced that professional progress and union membership simply cannot go hand in hand.'

"I do not see how engineers, the engineering profession and labor unions can possibly evade the following conclusions:

"(1) Draftsmen, testers, technicians, instrument men, calculators, inspectors, operators, and others in engineering-type occupations will find it practically impossible to achieve full professional standing if they belong to labor unions.

"(2) Labor unions are just as appropriate among draftsmen, testers, etc., who do not aspire to professional standing as they are in any other high-class, skilled craft.

"(3) If great numbers of professional engineers everywhere affiliate with labor unions, either because they choose to or because they are forced to, engineering occupations may continue to flourish but the profession of engineering, as such, will most assuredly vanish from the face of the earth."

STATEMENT BY THE BOARD OF DIRECTORS OF THE AMERICAN CHEMICAL SOCIETY*

Because of efforts to compel chemists and chemical engineers to join labor organizations in order to obtain or retain employment in certain plants, the board of directors of the American Chemical Society has given consideration to the broad problems of employment in the field of chemistry.

* From *Science*, **94** [2444] 418 (Oct. 31, 1941).

So that the position of the society may not be misunderstood, the board of directors issues the following statement:

The society has taken no stand against "collective bargaining" for professional men when such bargaining is not controlled by nonprofessional groups and where the bargaining unit is composed exclusively of professional men.

The society condemns no one of its members for joining any noncoercive labor union so long as he does so voluntarily.

The society, however, is unalterably opposed to the forcible inclusion of professional men in bargaining units dominated and controlled by nonprofessional employees, whether that inclusion be brought about by economic pressure on an employer, by intimidation of the professional employee, or by the operation of either state or federal law.

PERMANENT SCIENCE FUND OF AMERICAN ACADEMY OF ARTS AND SCIENCES*

Income from the Permanent Science Fund, according to agreement and declaration of trust, shall be applied by the American Academy of Arts and Sciences to such scientific research as shall be selected ". . . in such sciences as mathematics, physics, chemistry, astronomy, geology and geography, zoology, botany, anthropology, psychology, sociology and economics, history and philology, engineering, medicine and surgery, agriculture, manufacturing and commerce, education, and any other science of any nature or description, whether or not now known or now recognized as scientific, and may be applied to or through public or private associations, societies, or institutions, whether incorporated or not, or through one or more individuals."

Applications for grants under this indenture are considered by a committee of this Academy on stated dates only. The next meeting to consider applications will be held on February 15, 1942. Applications should be made on special forms furnished by the committee. Correspondence, including requests for application blanks, should be addressed to the chairman of the Committee on the Permanent Science Fund, John W. M. Bunker, Massachusetts Institute of Technology, Cambridge, Mass.

* From *Science*, **94** [2445] 432 (Nov. 7, 1941).

EXCERPTS FROM SECTION II: 4. TECHNICAL RESEARCH BY TRADE ASSOCIATIONS*

By Charles J. Brand

Abstract

Successful research by trade associations should benefit both association members and the consumers of the members' products.

Trade associations use various agencies for conducting research. A large number of associations maintain their own well-equipped, ably staffed laboratories; many use commercial research laboratories; some rely on university fellowships or financial grants to educational institutions; and others obtain the assistance of government agencies having research facilities, such as the National Bureau of Standards. Many other methods are available and used.

Among important research projects now being carried on by trade associations and, according to a recent survey, in the order mentioned as to frequency, are the search for additional sources of supply of standard materials or for new materials, efforts to improve standard products, investigation of outlets for the industry's products, and the search for new products that the industry can manufacture successfully and sell.

A major problem confronting trade association technical research is that of financing. Unless immediate practical results permit prompt returns to the industry, interest in research projects wanes and financing becomes increasingly difficult. Fundamental research is seldom of such a nature that the problem can be quickly solved. Financial arrangements should ensure reasonable continuity of research projects for periods sufficiently long to permit complete exploration of the possibilities involved. It should be financed, whenever possible, from the general funds of the association in order that all members may have equal rights in the results.

The results of trade association research should be made available to the members and the public as rapidly and completely as the definite findings warrant. Statistical valuation of the results obtained is not possible, but a great amount of benefit to the public at large has been obtained. The special equipment and trained personnel of trade association research organizations will be quickly and efficiently available to serve the people in any national emergency.

Technical research carried on by one industry may vitally affect other apparently entirely unrelated industries. Substitutes for standard commodities produced by one industry may be developed through technical research in another. Stainless steels, for instance, have almost completely supplanted some nonferrous metals and alloys for many uses where ordinary corrosion is an important factor. An industry may suddenly find that the entire outlet for its product has been captured by some other industry that it did not previously regard as in any sense competitive. The partly supplanted industry must find other outlets, better its methods or its products sufficiently to compete, or lose its market. Its entire economic existence may be at stake. The balance is upset and must be re-established. Often such an industry must turn to cooperative association research of one kind or another in order to solve its new problems and continue its operations. This situation is evidenced in the relation the artificial refrigeration industry bears to the natural and artificial ice industries. The expense of individual research effort is often prohibitive; a pooling of the knowledge, the experience, and the resources of an entire industry may be essential to the maintenance of its research activities.

The following News Letter was recently issued by the National Association of Manufacturers:

"Thirty-one per cent of the national manufacturing trade associations in the National Industrial Council conduct scientific research activities, according to a survey just completed by the Council in cooperation with the N.A.M. Advisory Committee on Scientific Research, of which Karl T. Compton, president of the Massachusetts Institute of Technology, is chairman.

"Of the 113 associations in the national manufacturing trade group, 35 conduct research activities and 11 have their own laboratories or cooperate with others in supporting laboratories. The average annual research budget of 27 associations reporting specific figures was $36,960. The median budget was $25,000. Two associations spend more than $100,000 a year.

"An average of 10 persons are employed in the laboratories operated by the associations reporting.

"Twenty-one of the associations finance research projects at universities, 7 at research foundations, and 3 at commercial laboratories.

"Most of the laboratories reported were established in the decade between 1920 and 1930.

"Approximately 34% of the associations take out patents on the products of their research activities. In the most instances, the patents are assigned to the association.

"Ten associations distribute information on the results of their research to members only and 25 make the results known to the public generally."

* From Research, A National Resource. A report of the National Research Council to the National Resources Planning Board. 370 pp. For sale by Superintendent of Documents, Washington, D. C. Price $1.00.

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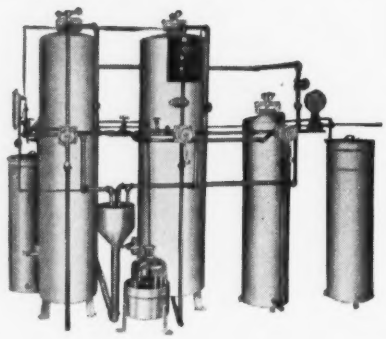

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AUTHOR INDEX TO THE BULLETIN

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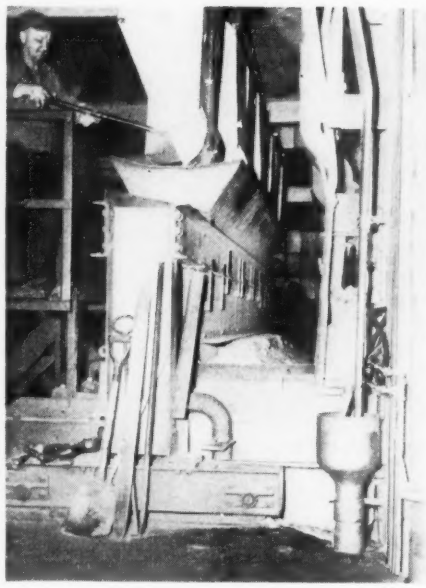

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Electro Refractories & Alloys Corp.
Louthan Mfg. Co.
Norton Co.
The Vitro Mfg. Co.

Body Stains
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel, O., Co., Inc.

Bone Ash
Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Borax
American Potash & Chemical Corp.
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pacific Coast Borax Co.
The Vitro Mfg. Co.

Borax Glass
American Potash & Chemical Corp.
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pacific Coast Borax Co.
The Vitro Mfg. Co.

Boric Acid (Anhydrous)
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pacific Coast Borax Co.
The Vitro Mfg. Co.

Boric Acid (Crystal, Granular, or Powder)
American Potash & Chemical Corp.
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pacific Coast Borax Co.
The Vitro Mfg. Co.

Boron Carbide
Norton Co.

Brick Machines (also Barrows, Molds)
Lancaster Iron Works, Inc.

Brick (Refractory)
Carborundum Co. (*"Carbofrax Aloxite"*)
Corhart Refractories Co.
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
Norton Co.
The Vitro Mfg. Co.

Cadmium Sulphide
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Carbofrax (Refractory Products)
Carborundum Co.

Carbonates (Barium, Lead)
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Castings
Lancaster Iron Works, Inc.

Caustic Potash
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Solvay Sales Corp.

Caustic Soda
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.
Solvay Sales Corp.
The Vitro Mfg. Co.

Cements
Carborundum Co.
Corhart Refractories Co.
Electro Refractories & Alloys Corp.
Norton Co.
Pennsylvania Salt Mfg. Co.
Sauereisen Cements Co.

Ceramic Chemicals
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
Pennsylvania Salt Mfg. Co.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Ceramic Specialties
American Lava Corp.

Cerium Oxide
Drakenfeld, B. F., & Co.
Foote Mineral Co.

Chromite (Natural Chromate of Iron)
Foote Mineral Co.

Chromium Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Clay (Ball)
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Kentucky Clay Mining Co.
Maxson, Elwyn L.
Paper Makers Importing Co.
Potters Supply Co.
Spinks, H. C., Clay Co.
United Clay Mines Corp.
The Vitro Mfg. Co.

Clay (Bentonite)
American Colloid Company
Great Lakes Foundry Sand Co.

Clay (Block)
Du Pont de Nemours, E. I., & Co., Inc., R. &. H. Chemicals Dept.

Clay (China)
Ceramic Color & Chemical Mfg. Co.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.
Thomas Alabama Kaolin Co.
United Clay Mines Corp.
The Vitro Mfg. Co.

Clay—Cleaners, Feeders
Lancaster Iron Works, Inc.

Clay (Electrical, Porcelain)
Ceramic Color & Chemical Mfg. Co.
Hammill & Gillespie, Inc.
The Hommel, O., Co., Inc.
Kentucky Clay Mining Co.
Maxson, Elwyn L.
Paper Makers Importing Co.
Spinks, H. C., Clay Co.
Thomas Alabama Kaolin Co.
United Clay Mines Corp.

Clay (Enamel)
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Kentucky Clay Mining Co.
Maxson, Elwyn L.
Metal & Thermit Corp.
Paper Makers Importing Co.
Porcelain Enamel and Mfg. Co.
Spinks, H. C., Clay Co.
Thomas Alabama Kaolin Co.
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United Clay Mines Corp.
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Potters Supply Co.
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United Clay Mines Corp.

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Harshaw Chemical Co.
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Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

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National Engineering Co.

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Lancaster Iron Works, Inc.

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Frazier-Simplex, Inc.
Lancaster Iron Works, Inc.
Proctor & Schwartz, Inc.
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Corhart Refractories Co.

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Denver Fire Clay Co.
Great Lakes Foundry Sand Co.
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Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
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Harshaw Chemical Co.
The Hommel, O., Co., Inc.
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Norton Co.

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Harshaw Chemical Co.
The Hommel, O., Co., Inc.

French Flint
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Ceramic Color & Chemical Mfg. Co.
Harshaw Chemical Co.
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Ceramic Color & Chemical Mfg. Co.
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Eureka Flint & Spar Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.

Goggles
The Hommel, O., Co., Inc.

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Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

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The Hommel, O., Co., Inc.

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Norton Co. (*Crystolon*)

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Norton Co.

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Harshaw Chemical Co.
The Hommel, O., Co., Inc.

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Harshaw Chemical Co.

Iron (Enameling)
American Rolling Mill Co.

Iron Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Kaolin
Ceramic Color & Chemical Mfg. Co.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.
Thomas Alabama Kaolin Co.
United Clay Mines Corp.
The Vitro Mfg. Co.

Kilns, China (Decorating)
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Frazier-Simplex, Inc.
The Hommel, O., Co., Inc.
Swindell-Dressler Corp.

Kilns (Electric, Circular, Tunnel)
Swindell-Dressler Corp.

Kiln Furniture (Silicon Carbide, Semi-Silicon Carbide) (Refractory)
Electro Refractories & Alloys Corp.
Louthan Mfg. Co.

Kryolith (see Cryolite)
Pennsylvania Salt Mfg. Co.

Laboratory Ware
Norton Co.

Lehr Tile (High Aluminous Clay, Electrically Sintered Aluminum Oxide, Silicon Carbide)
Carborundum Co.
Electro Refractories & Alloys Corp.

Lehrs
Frazier-Simplex, Inc.
Swindell-Dressler Corp.

Lehrs (Electric or Fuel Heated)
Frazier-Simplex, Inc.
Swindell-Dressler Corp.

Lehr Loaders
Frazier-Simplex, Inc.

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Corhart Refractories Co.
Denver Fire Clay Co.
Electro Refractories & Alloys Corp.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Norton Co.
The Vitro Mfg. Co.

Lithium Carbonate
Drakenfeld, B. F., & Co.
Foote Mineral Co.

Lithium Minerals
Foote Mineral Co.

Loaders (Bucket)
National Engineering Co.

Magnesia (Fused)
Electro Refractories & Alloys Corp.
Norton Co.

Magnesia (Sintered, Calcined)
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.

Magnesite
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Magnesite Calcined
Foote Mineral Co.
The Hommel, O., Co., Inc.

Magnesium Carbonate
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Manganese
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Manganese Dioxide
Drakenfeld, B. F., & Co.
Foote Mineral Co.

Manganese (Oxide)
Ceramic Color & Chemical Mfg. Co.
Corhart Refractories Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Masks (Breathing)
Drakenfeld, B. F., & Co.

Metals (Porcelain Enameling)
American Rolling Mill Co.

Micronized Products
Porcelain Enamel and Mfg. Co.

Microscopes (Polarizing)
Bausch & Lomb Optical Co.
Spencer Lens Co.

Microscopes (Stereoscopic)
Spencer Lens Co.

Minerals
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
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The Hommel, O., Co., Inc.
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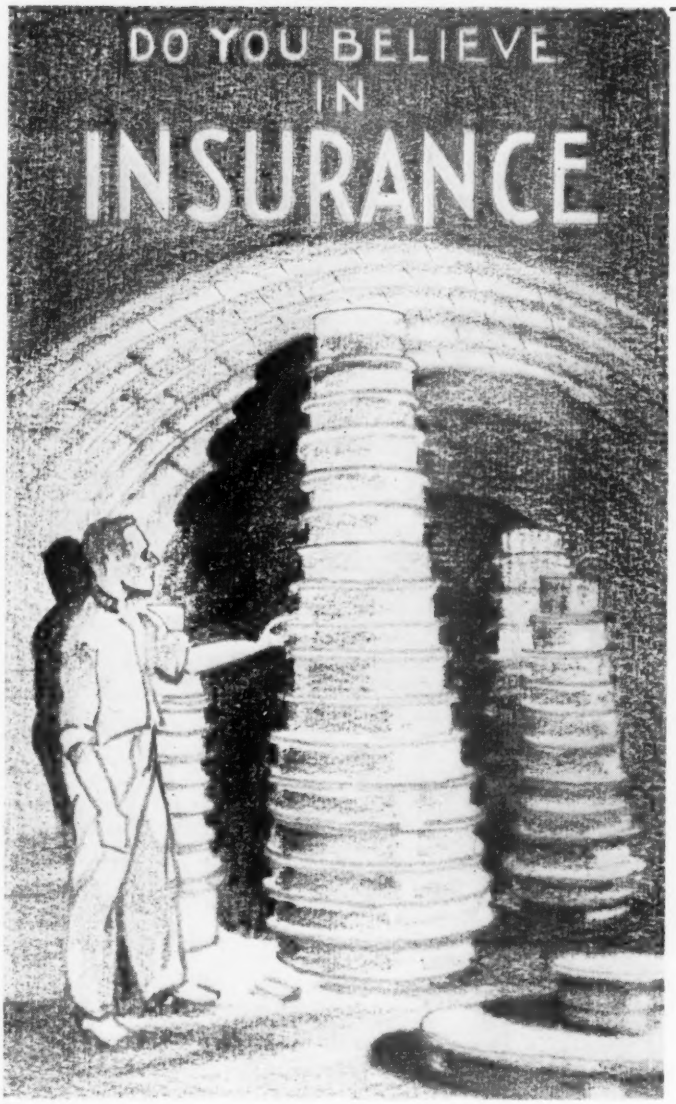

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THE BULLETIN OF THE AMERICAN CERAMIC SOCIETY

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THE BULLETIN OF THE AMERICAN CERAMIC SOCIETY